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# An Educational Framework for Course Development*

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*This paper develops a model of education and applies the model to the development of a course in industrial quality engineering. A cognitive constructionist view of learning and instruction is used to develop the educational model. Some behavioural concepts are used from an instructional perspective to balance the cognitive constructionist foundation. A three-phase technique in course development and instruction is offered that balances not only the behavioural and the cognitive-mediational theories, but also attempts to strike a balance between education and training, an essential point in science/engineering-based education*

## INTRODUCTION

THE importance of education and pedagogy to society is often debated [1–4]. The discussion often leads to the need for improved education and the search for better ways to educate are almost endless [5–10]. This article addresses some aspects of the need to enhance engineering education through course development. (See Fig. 1 for a thought diagram of the development of this paper's logical flow.) First, we will look at what is known about learning itself from the literature, extracting relevant critical ideas. Next we extract crucial concepts from instruction theory to form the basis for a conception of instruction. From the knowledge acquired about learning and instruction, we proceed to build a model of education that reflects our beliefs of how to approach the education of scientists and engineers. This educational concept for course development is then applied to a course for industrial quality engineering. We conclude with some thoughts on this work and how it may be applied. The appendix contains a sample of the course syllabus for the quality engineering course.

## TOWARD AN UNDERSTANDING OF LEARNING AND INSTRUCTION

To enumerate the myriad of notable works written in the areas of learning and instruction is both beyond the scope of this paper and, quite frankly, has already been done. To have the foundation on which to build a concept of learning and instruction, this paper draws heavily on the work of Anderson [11, 12], McKeachie [9, 10] and Levinson-Rose and Menges [8]. The basic idea behind Anderson's development of a 'cognitive constructionist conception' of learning and instruction is that 'in order to help beginning teachers construct such theories and think about their instructional responsibilities, teacher educators may draw on a large and emerging knowledge base about learners, learning, and classroom instruction' [11, p. 85]. Anderson grounds this idea on two premises. 'First, teachers hold conceptions of learning and instruction that function as personal theories to guide decisions about teaching practice; and second, teacher educators can (and should) influence the development of these conceptions through the curriculum for teacher education [11, p. 85]. In a way this paper is influenced by and is an attempt to fulfill this ideal.

### *What do we know about learning?*

Learners are active and constructive problem solvers and learning is a learner-mediated process. The cognitive constructionist view holds that learning occurs when the learner acts upon information and relates it to existing knowledge by imposing organization and meaning to the experience [11, 13]. Learning can be viewed as either receptive–accrual in nature (what we know as traditional learning) or it can be cognitive–mediational (as was described in the above quote). The receptive–accrual perspective views learning as a function of receptivity to information, depending heavily on the ability, intelligence and effort of the learner. The teacher is the provider of information, tasks and incentives to perform. The cognitive–mediational perspective sees students as active, constructive, problem solvers and the teacher as

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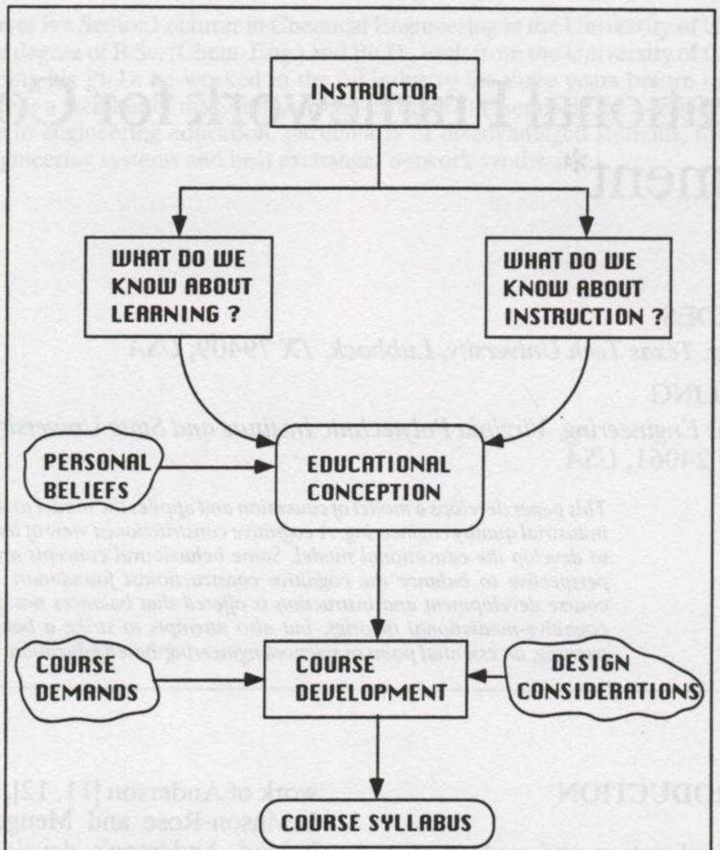


Fig. 1. Thought diagram of a conceptual model for course development.

influencing students' cognitive processes based on intrinsic motivation. Anderson compiled the work on learning into nine organizing ideas (see Fig. 2). A flow diagram to capture the nine organizing ideas on learning is provided in Fig. 3.

*Critical ideas in learning*

The critical ideas from Fig. 2 can be summarized into five points. First, learning requires students self-regulate their learning and, thus, reorganize information in a way that is consistent with their

**ORGANIZING IDEAS ABOUT LEARNING**

**# 1- Each individual is a unique knowledge organizer.**

**# 2- An individual's schemas shape their perception, understanding, & memory.**

**# 3- An individual's knowledge is a 'domain specific' growth blend (building blocks) of instruction and experience.**

**# 4- Learners regulate their cognition during learning and problem solving.**

**# 5- Successful learners engage metacognitive knowledge and experience.**

**# 6- Self regulation is a social-environment, time dependent, problem solving, mentored growth process.**

**# 7- A learner's academic success is dependent on (a) self perceptions of academic confidence and domain outcome control, and (b) belief about cause and effect relationships of success and failure.**

**# 8- A learner's task related goals are associated with different cognitive activities and thus, determines metacognitive strategies in task performance.**

**# 9- Student motivation is affected by the classroom social and task structure.**

Fig. 2. Organizing ideas on learning.

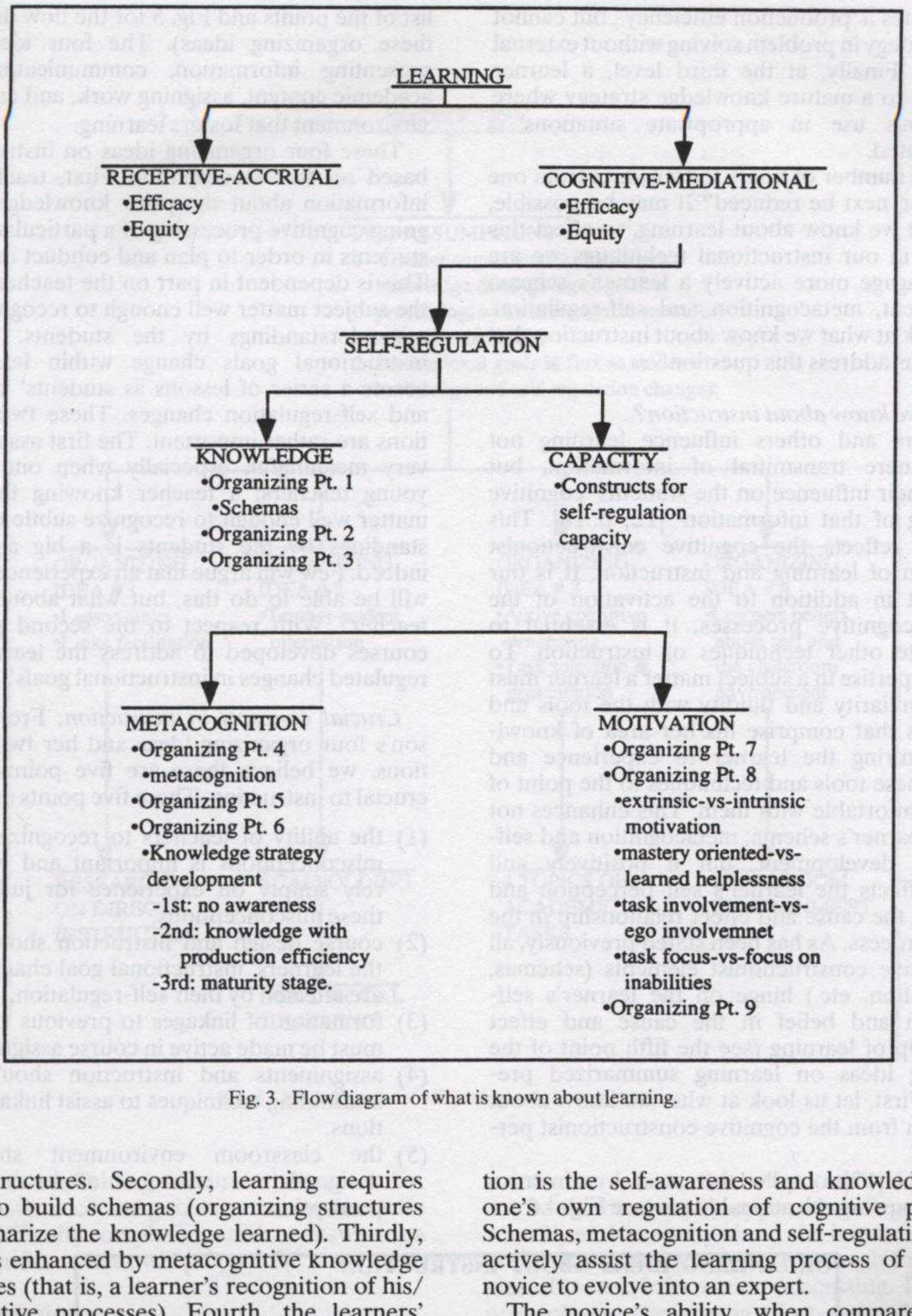


Fig. 3. Flow diagram of what is known about learning.

mental structures. Secondly, learning requires learners to build schemas (organizing structures that summarize the knowledge learned). Thirdly, learning is enhanced by metacognitive knowledge experiences (that is, a learner's recognition of his/her cognitive processes). Fourth, the learners' socio-environmental experiences influence their self-regulation, schema development, and metacognition development mentioned above, as well as their motivation to learn. Finally, self-perception and knowledge of cause and effect relationships in the learning process are crucial to the learner being able to develop all that we have mentioned so far.

A schema is an organizational structure that summarizes the knowledge about various situations that are linked to one another based on their differences and similarities [11, 13–17]. Metacognition is another concept that is viewed as critical by researchers in the area of education. Metacognition is the self-awareness and knowledge about one's own regulation of cognitive processes. Schemas, metacognition and self-regulation in part actively assist the learning process of getting a novice to evolve into an expert.

The novice's ability, when compared to an expert's ability to develop knowledge strategies, is another facet of learning to be considered. To reach the level of an expert, a novice needs many hours of effort to build the schemas and metacognition abilities associated with experts. Expertise is related to what is termed 'knowledge strategy development' (the ability to know and apply knowledge strategies of a subject area to resolve, analyze, design, or develop solutions) [9, 11]. This knowledge strategy development is seen as a continuum of three levels. At the first level a learner has no awareness of the knowledge strategies. At the second level, the learner 'knows' the strategy and demonstrates a 'production efficiency', but cannot use the strategy in problem solving without external assistance. Finally, at the third level, a learner progresses to a mature knowledge strategy where spontaneous use in appropriate situations is demonstrated.

Can the number of hours to transition from one level to the next be reduced? It may be possible, from what we know about learning, to affect this barrier if in our instructional techniques we are able to engage more actively a learner's schema development, metacognition and self-regulation. Let us look at what we know about instruction that may help us address this question.

*What do we know about instruction?*

'Teachers and others influence learning not through mere transmittal of information, but through their influence on the students' cognitive processing of that information' [12, p. 18]. This statement reflects the cognitive constructionist conception of learning and instruction. It is our belief that in addition to the activation of the learners' cognitive processes, it is essential to incorporate other techniques of instruction. To achieve expertise in a subject matter a learner must obtain familiarity and fluidity with the tools and techniques that comprise his/her area of knowledge, requiring the learner to experience and practice these tools and techniques to the point of feeling comfortable with them. This enhances not only the learner's schema, metacognition and self-regulation development, but it positively and actively affects the learner's self perception and valence in the cause and effect relationship in the learning process. As has been stated previously, all the cognitive constructionist elements (schemas, metacognition, etc.) hinge on the learner's self-perception and belief in the cause and effect relationship of learning (see the fifth point of the organizing ideas on learning summarized previously). First, let us look at what we know about instruction from the cognitive constructionist perspective.

Anderson [12] compiled the research on instruction into four organizational ideas (see Fig. 4 for a list of the points and Fig. 5 for the flow diagram of these organizing ideas). The four ideas cover presenting information, communicating about academic content, assigning work, and creating an environment that fosters learning.

These four organizing ideas on instruction are based on two assumptions. First, teachers have information about the prior knowledge and on-going cognitive processing of a particular group of students in order to plan and conduct instruction. This is dependent in part on the teacher knowing the subject matter well enough to recognize subtle misunderstandings by the students. Secondly, instructional goals change within lessons and across a series of lessons as students' knowledge and self-regulation changes. These two assumptions are rather important. The first assumption is very meaningful, especially when one looks at young teachers; a teacher knowing the subject matter well enough to recognize subtle misunderstandings by the students is a big assumption indeed. Few will argue that an experienced teacher will be able to do this, but what about a novice teacher? With respect to the second point, are courses developed to address the learners' self-regulated changes in instructional goals?

*Crucial concepts in instruction*. From Anderson's four organizing ideas and her two assumptions, we believe there are five points that are crucial to instruction. These five points are

(1) the ability of teachers to recognize learners' misconceptions is important and we cannot rely simply on experience for judgment of these misconceptions,
(2) course design and instruction should reflect the learners' instructional goal changes which are affected by their self-regulation,
(3) formation of linkages to previous knowledge must be made active in course assignments,
(4) assignments and instruction should reflect scaffolding techniques to assist linkage formations,
(5) the classroom environment should be designed to enhance a learner's self-perception.

**ORGANIZING IDEAS ABOUT INSTRUCTION**

**# 1- A learner's perception of lesson linked to main ideas will enhance his/her learning. Teachers can facilitate these linkage formations among main ideas through well planned and organized lessons.**

**# 2- Teacher-student academic content interactions (dialogues) through the use of 'scaffolding' and 'fading' are crucial in learners building linkages among ideas and thus obtaining knowledge construction and self regulation.**

**# 3- Learning is facilitated by engaging learners in active cognitive processing of academic content through the use of academic tasks. Learners' cognitive processing quality is determined by teacher task selection and presentation.**

**# 4- A learner's beliefs about him/herself and school tasks are influenced by a teacher's decisions about classroom structure and organization.**

Fig. 4. Organizing ideas on instruction.

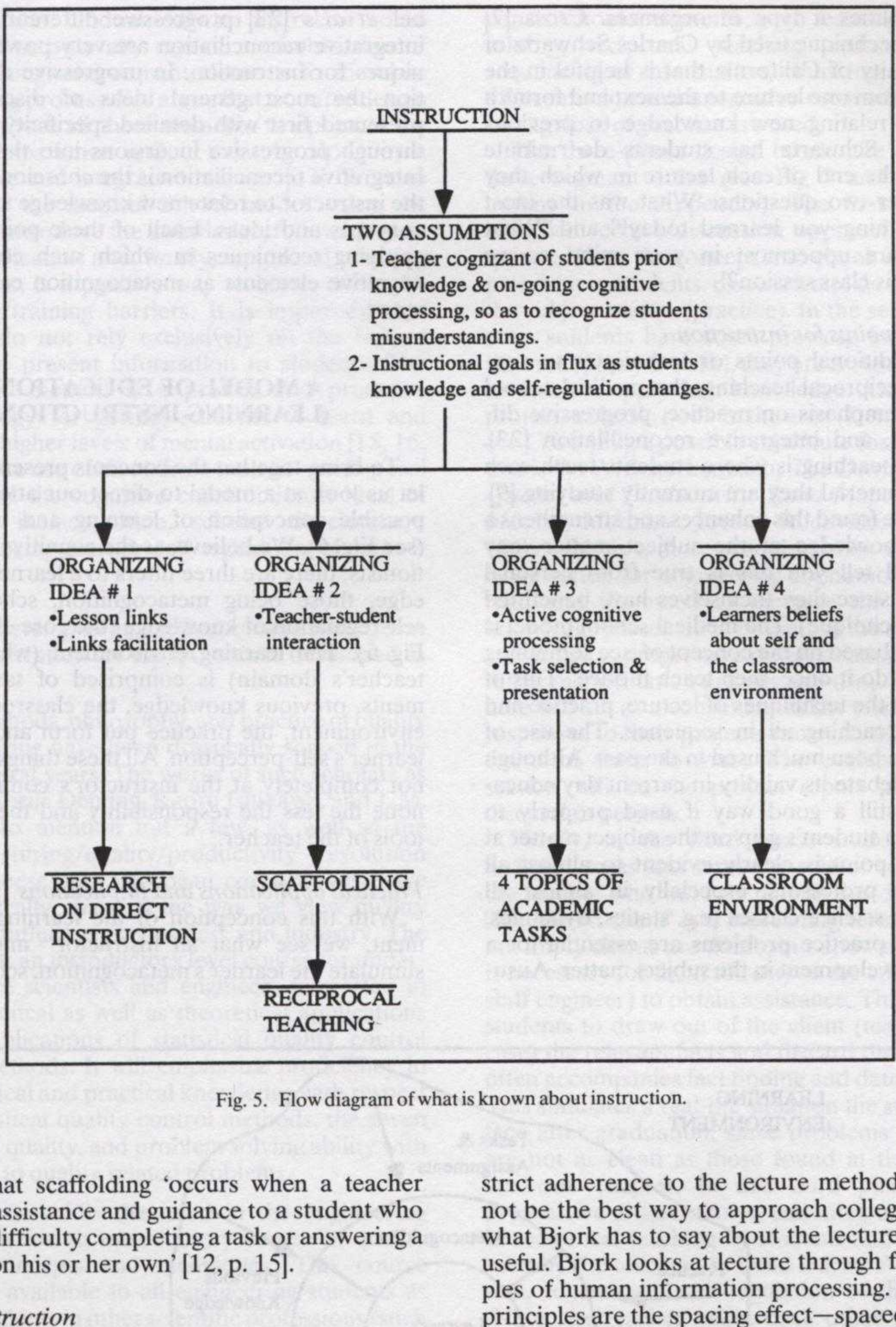


Fig. 5. Flow diagram of what is known about instruction.

Note that scaffolding 'occurs when a teacher provides assistance and guidance to a student who is having difficulty completing a task or answering a question on his or her own' [12, p. 15].

*Direct instruction*

In addition to these five points, there are other issues or techniques important to recognize. There are times when direct instruction is a good method, especially in a freshman or sophomore class where the student has little or no knowledge of the subject matter. In cases where the discussion format is used in these types of classes, the level and depth of discussion are often poor. Thus, improving the direct lecture method is important. Bjork [18], believes there are three important aspects to college teaching: how to study, course design and the lecture. Bjork addresses college teaching from a strictly lecture-oriented perspective. Although this strict adherence to the lecture methodology may not be the best way to approach college teaching, what Bjork has to say about the lecture method is useful. Bjork looks at lecture through four principles of human information processing. These four principles are the spacing effect—spaced presentations yield better long-term recall, variable encoding, levels of processing and the importance of structure. These points need to be addressed to avoid short-term memory overload. Suggestions to improve the lecture method include careful and evident structure of material, well-defined sequence and moderate pace, reviewing prior knowledge at the start of each lesson, relating new information to prior knowledge covered in the course and providing organizers and outlines for students to follow (for further information on improving instruction see [5–8, 10, 19–22]). Figure 1 of this paper is an example of a thought diagram that exemplifies a type of organizer. Cross [7] presents a technique used by Charles Schwartz of the University of California that is helpful in the transition from one lecture to the next and forms a bridge for relating new knowledge to previous knowledge. Schwartz has students do 'minute papers' at the end of each lecture in which they must answer two questions: 'What was the most important thing you learned today?' and 'What questions are uppermost in your mind as we conclude this class session?'

*Additional points for instruction*

Some additional points or techniques to consider are reciprocal teaching, the medical school model, an emphasis on practice, progressive differentiation, and integrative reconcilliation [23]. Reciprocal teaching is where students teach each other the material they are currently studying [9]. Studies have found this enhances and strengthens a learner's knowledge of the subject matter (any teacher will tell you this is true from personal experience since they themselves have benefitted from this technique). The medical school model is simple. It is based on the concept of 'see something done once, do it once, then teach it once'. This of course uses the techniques of lecture, practice and reciprocal teaching all in sequence. The use of practice has been much used in the past. Although some will debate its validity in current day education, it is still a good way if used properly to strengthen a student's grip on the subject matter at hand. This point is clearly evident to almost all engineering professors, especially in almost all engineering science classes (e.g. statics, dynamics, etc.) where practice problems are essential for a student's development in the subject matter. Ausubel *et al.*'s [23] progressive differentiation and integrative reconciliation are very powerful techniques for instruction. In progressive differentiation the most general ideas of discipline are presented first with detailed specificity increased through progressive incursions into the material. Integrative reconciliation is the conscious effort by the instructor to relate new knowledge to previous concepts and ideas. Each of these points add to applying techniques in which such constructive cognitive elements as metacognition can be activated.

## A MODEL OF EDUCATION (LEARNING INSTRUCTION)

To bring together the concepts presented so far, let us look at a model to direct our attention to a possible conception of learning and instruction (see Fig. 6). We believe, as the cognitive constructionists, there are three filters to a learner's knowledge, those being metacognition, schemas and self-regulation of knowledge (the core elements in Fig. 6). The learning environment (which is the teacher's domain) is comprised of task assignments, previous knowledge, the classroom socio-environment, the practice put forth and, yes, the learner's self-perception. All these things, although not completely at the instructor's command, are none the less the responsibility and the potential tools of the teacher.

*Practical applications and implications*

With this conception of the learning environment, we see what an instructor might do to stimulate the learner's metacognition, schemas and

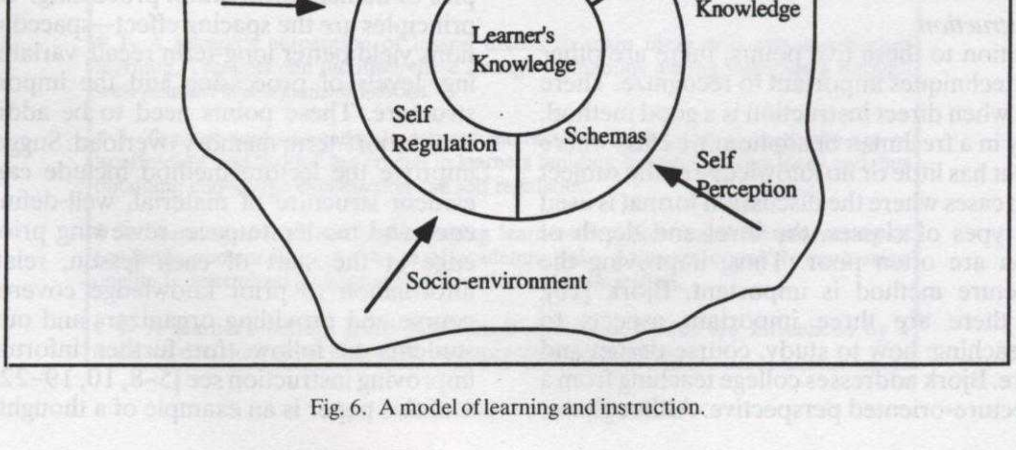


Fig. 6. A model of learning and instruction.

self-regulation. Undoubtedly an instructor could choose to activate any one or a combination of these learning environment elements to stimulate the learning process. We argue that a course design should activate all these elements to optimize the learning experience and it must be done in a progressive and integrative manner [23]. We also argue that the medical school model, using the lecture to introduce the knowledge, followed by an active application and, finally, reciprocal teaching endeavours, is a positive way to break down the education/training barriers. It is important that teachers do not rely exclusively on the lecture method to present information to students. The case study method is a proven and proactive methodology for getting students to learn and engage in higher levels of mental activation [15, 16, 24–26]. The use of all of these tools at our disposal approaches the cognitive constructionist ideal of activating metacognition, schema development and enhancing learner self-regulation of knowledge.

*A course development, application and description*

The description for the QC course developed as follows.

> The methods, philosophy, and practice of quality engineering have been drastically shaped in the last several years. The works of such scholars as W. Edwards Deming, Kaoru Ishikawa, and J. M. Juran, to mention but a few, as well as the manufacturing/quality/productivity revolution of Japanese and European corporations, have dramatically changed the way we view quality and its influence on business and industry. The course is an introductory level course for undergraduate scientists and engineers interested in the practical as well as theoretical applications and implications of statistical quality control over methods. It will emphasize proficiency in theoretical and practical knowledge with respect to statistical quality control methods, the seven tools of quality, and problem solving ability with respect to quality related problems.

This course fills the need in the engineering curriculum for an introductory course in quality control concepts and techniques. This course would be available to all engineering students as well as students in other scientific professions (such as physics, chemistry, etc.).

*Conceptual course design*

This course is designed to maximize the points covered in earlier sections of this paper. The major conceptual point of the course design is the three-phase instructional model. This draws heavily on the medical school model of 'see one, do one, teach one'. The three-phase design is also used to build the cognitive constructionist elements of helping students develop schemas and metacognition, self-regulation and progressively building knowledge on previous knowledge. Along with the cognitive constructionist elements, such techniques as scaffolding, reciprocal teaching, redundancy and sequencing of information, chunking, progressive differentiation and integrative reconciliation and a strong dose of practice are used.

The three-phase design breaks the course into three segment areas (see Fig. 7 and the course outline in the Appendix). The first phase is a modified lecture/discussion approach with daily quizzes. Here the concept is to chunk information, present it to students, discuss it and do exercises on the subject matter (practice). In the second phase, once students have some previous knowledge of the area (phase 1 work), they are assigned a project to which to apply their knowledge. Along with the project, a classic book in the area (Deming's *Out of the Crisis* [27]; a possible substitute for the Deming text is W. W. Scherkenbach, *The Deming Route to Quality and Productivity: Road Maps and Roadblocks*, Mercury Press, Rockville, Maryland, 1986—this is a more readable book that may be more suited for engineering sophomores), will be read and discussed to increase the breadth of knowledge presented in phase 1 of the course (here redundancy, progressive differentiation and integrative reconciliation are put into use). The teacher here will act as a consultant as the students design responses to their projects (note: students work in teams of three to four). The evaluation of this section will be the project report plus in-class discussion periods.

Finally, in the third phase students will be assigned cases and serve the role of consultant to the teacher who will role play as the 'dumb client'. The 'dumb client' is a misleading term. This does not imply clients are dumb, but unaware of all that is necessary for them to relay to the consultant (or staff engineer) to obtain assistance. This forces the students to draw out of the client (teacher in this case) the relevant facts and discard the 'noise' that often accompanies fact finding and data collection. This simulates a real-life situation the students will face after graduation, since problems in industry are not as clean as those found at the end of a textbook chapter. In this third phase we see progressive differentiation and integration, as well as reciprocal teaching by students and scaffolding used by the teachers to build learners' metacognition, schema and self-regulation of the material. (Note: the teacher might have other teachers or people from industry to play the 'dumb client' role to add diversity to the cases. The evaluation of this section will be short case reports.)

*How the course will be taught, evaluated and developed*

Along with what has been mentioned above, the students develop a process flow diagram of the knowledge they are gaining through this course. Throughout the year, in the quizzes or assignments, the students are asked to show their diagrams and explain them. Of course the students' flow diagrams will reflect their conception of the knowl-

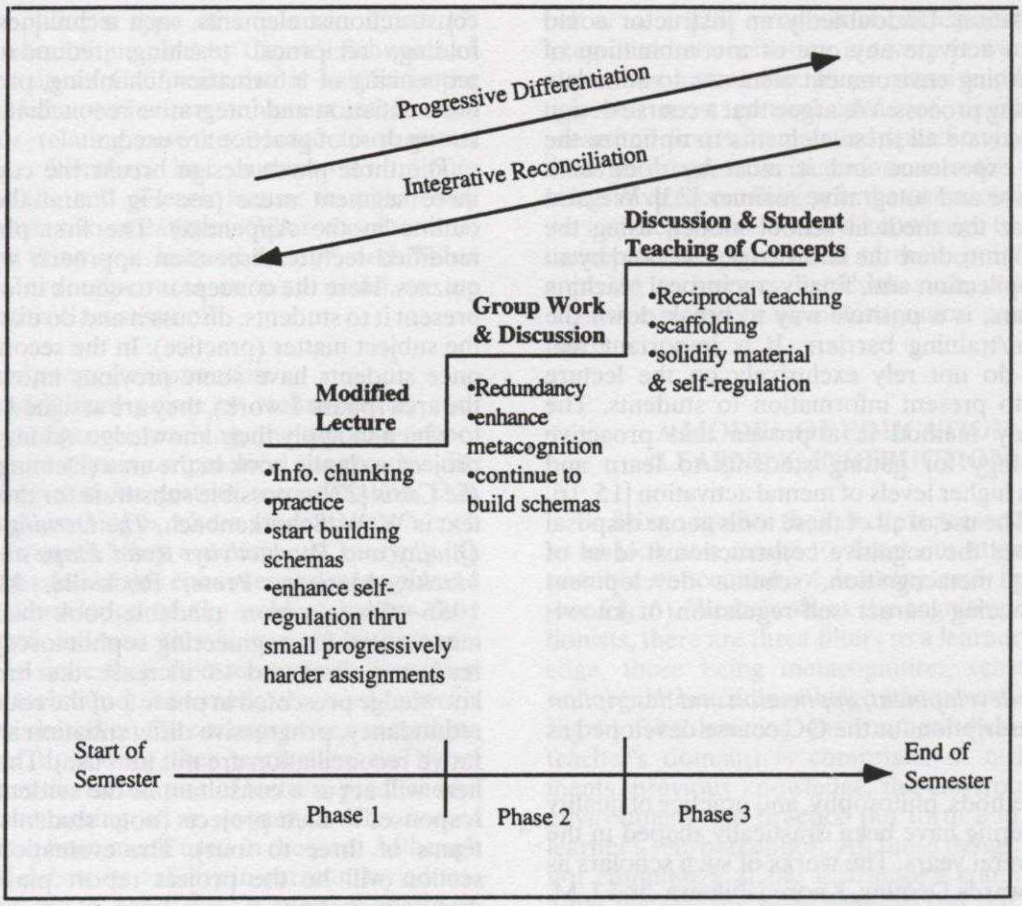


Fig. 7. Conceptual model of three-phase design.

edge they have acquired on the subject. This provides an active way for learners to self-regulate their learning. The diagram will be due the last day of classes. At the end the students are asked to reproduce their diagrams and explain them. This diagram construction will assist their schema, metacognition and self-regulation development of the subject area. The question at the end will verify if they have enhanced these cognitive elements.

The course, being taught in three different phases and teaching styles with three different levels of processing, requires learners to build constructive cognitive learning (see Fig. 7). Along with the regular outside assignments, we use some in-class assignments (see the course outline in the Appendix—the beer game and red beads experiment). These enhance learning and activate the different levels of processing in the students.

## THOUGHTS AND CONCLUSIONS

The course is an attempt to incorporate our learning/instruction schema; it will most probably undergo many revisions. We plan to have students fill out an evaluation instrument after each section or phase of the instruction so we may improve each. This three phase design incorporates such techniques as scaffolding, reciprocal teaching, redundancy and sequencing of information, chunking, progressive differentiation and integrative reconciliation, as well as practice elements that stimulate self-regulation and metacognitive and schema development. The method repeats the course knowledge three times in different formats to stimulate the learners' cognitive construction of that knowledge. Students are virtually seeing the same material thrice. The method also sets a cooperational environment with defined goals to enhance the learners' potential for success and positive self-perception. Finally, although this course development paradigm has been used to create a course in quality engineering, the three-phase design is by no means restricted to this subject matter. To bridge the gap between education and training, efforts such as these need to be developed, implemented and improved upon. Many question or debate the education/training issue. But few will argue that industry needs engineers who are both knowledgeable (education) of the subject matter and possess the ability to apply such knowledge (training) to the resolution of problems in the work place.

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## APPENDIX: COURSE OUTLINE

*Practical methods in quality control theory for engineering ISE 2xxx (INDEX #YYYY)*

*Course description*. The methods, philosophy and practice of quality engineering have drastically been shaped in the last few years. The works of such scholars as W. Edwards Deming, Kaoru Ishikawa and J. M. Juran to mention but a few, as well as the manufacturing/quality/productivity revolution of Japanese and European corporations, have dramatically changed the way we view quality and its influence on business and industry. This course is an introductory level course for undergraduate scientists and engineers interested in the practical as well as theoretical applications and implications of statistical quality control methods. It will emphasize proficiency in theoretical and practical knowledge with respect to statistical quality control methods, the seven tools of quality and problem solving ability with respect to quality-related problems.

*Major concepts and techniques*.

1. Statistical quality control theory.
2. The seven tools of quality: histograms, cause-and-effect diagrams, check sheets, Pareto diagrams, control charts, scatter diagrams, and process flow diagrams.
3. Pareto principle.
4. Data collection and graphing.
5. Process analysis.
6. Process capability.
7. Binomial probability.
8. Sampling and sampling inspection.
9. Quality management theory.
10. Deming's concept of 'profound knowledge'.

*Educational objectives*. The educational objectives of this course are to present undergraduate science and engineering students with the major concepts and techniques involved in statistical quality control theory and management. Upon completion of this introductory course students will have obtained the basic knowledge in quality control theory and practice (practical application of the concepts and theory) so as to solve basic level quality-related problems. This course is a helpful first course for those students interested in continuing their education and training in quality control engineering.

Instructor:

Name . . .

Office: __________

Telephone: __________

Office hours: __________

Class meeting time and room:

Tuesdays and Thursdays 00:00–00:00 in __________

*Texts*

1. K. Ishikawa, *Guide to Quality Control*, Asian Productivity Organization, Tokyo, Japan (1987).
2. W. E. Deming, *Out of the Crisis*, MIT Press, Cambridge, MA (1986).
3. Instructors handout of selected readings.

*Grading*. All assignments are due at the beginning of the class period designated in the syllabus. Any late assignment will be graded as a zero. Exceptions to this policy must be cleared with the professor prior to the assignment's date. The grading scale is as follows. Note: I reserve the right to increase your grade based on class participation.

| | |
|---|---|
| A | 90–100 |
| B | 80–89 |
| C | 70–79 |
| D | 60–69 |
| F | below 60 |

The grading will be based on the following assignments.

| | |
|---|---|
| Daily quizzes | 15% |
| Midterm | 15% |
| Final exam | 15% |
| Project | 15% |
| Quality PFD | 10% |
| Cases | 15% |
| Assigned problems | 15% |
| | 100% |

Practical methods in quality control theory for engineering ISE 2xxx (INDEX YYYY)

| Week/class | Date | Topic | Reading assignment | Other assignment |
|---|---|---|---|---|
| W1C1 | xx/xx/xx | How to collect data | Ishikawa (1) | |
| | | Concept of systems | Skrabec (1990) | Problem 13.1 |
| W1C2 | – | Check sheets and process flow diagrams | Ishikawa (4) Burr (1990a, e) | Problem 13.4 |
| W2C3 | – | Histograms | Ishikawa (2) Burr (1990d) | Problem 13.2 |
| W2C4 | – | CE diagrams | Ishikawa (3) Burr (1990b) | Problem 13.3 |
| W3C5 | – | Pareto diagrams | Ishikawa (5) Burr (1990f) | Problem 13.5 |
| W3C6 | – | Scatter diagrams | Ishikawa (9) Burr (1990g) | Problem 13.9 |
| W4C7 | – | Control charts I | Ishikawa (7) Burr (1990c) | Problem 13.7 |
| W4C8 | – | Control charts II | Ishikawa (8) | Problem 13.8 |
| W5C9 | – | Binomial probability | Ishikawa (10) | |
| W5C10 | | S/A | S/A | Problem 13.10 |
| | | Process capability | Rado (1989) | |
| W6C11 | – | Sampling | Ishikawa (11) | Problem 13.11 |
| W6C12 | | Sampling inspection | Ishikawa (12) | Problem 13.12 |
| W7C13 | – | Review class—midterm | | |
| W7C14 | | MIDTERM | | |
| W8C15 | – | Review midterm exam | Current events hand in | |
| W8C16[a] | | Advanced quality concepts (loss function, key product and process characteristics, etc.) | instructor handout | |
| W9C17 | – | Quality, productivity and management transforming western management | Deming (1, 2) | |
| W9C18 | | Disceases and obstacles | Deming (3, 4) | Red beads experiment |
| W10C19 | – | Questions to help managers Quality and the customer | Deming (5, 6) | |
| W10C20 | | Service organization quality Training and leadership | Deming (7, 8) | |
| W11C21 | – | Operational definitions Standards and Regs. | Deming (9, 10) | |
| W11C22 | | Variation Downstream improvement | Deming (11, 12) | The beer game |
| W12C23 | – | Some disappointments Two reports to management | Deming (13, 14) | |

| Week/class | Date | Topic | Reading assignment | Other assignment |
|---|---|---|---|---|
| W12C24 | | Minimum average total cost<br>Organization for quality and productivity | Deming (15, 16) | Project report due |
| W13C25[b] | | Students consulting | Case (1) | |
| W13C26 | | | Case (2) | Case 1 report |
| W14C27 | – | Students consulting | Case (3) | Case 2 report |
| W14C28 | | | Case (4) | Case 3 report |
| W15C29 | – | Students consulting | Case (5) | Case 4 report |
| W15C30 | | Review for final | | Case 5 report and quality PFD |
| | | Final exam | | |

[a]Phase 2 begins; group work starts here. Each class session includes applications of tools discussed during the first 6 weeks.
[b]Phase 3 begins at this point.

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