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Designing Interactive Teaching–Learning Systems for Technical Education*

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With the rapid growth of science and technology the central task of educational institutes is to prepare students to face the problem-solving situations of tomorrow. Efforts in making qualitative improvements in the traditional teacher-centred teaching–learning systems have had only marginal effects, resulting in continued criticism from employers and the dissatisfaction of students as well as teachers. This paper presents four conceptual models of teaching–learning designed to provide opportunities to the learner to develop real-life problem-solving abilities through an interactive process. The study reported here, which extended over a period of 2 years, has been conducted in four polytechnics in India in collaboration with 62 large- and medium-scale industries.

INTRODUCTION

IN THE rapidly changing technological societies of today the skills that are required need to be flexible and transferable, i.e. people should be able to take skills from one job to another, or from one industry to another, and should be able to build upon and change their skills in response to demands [1].

The requirements today are for basic skills, including skills in thinking logically, in problem solving and in handling information, and the development of attitudes such as flexibility and willingness to work co-operatively with others. Thus the content and methods of education need essentially to prepare students to face the unknown.

The shift that has to take place in the content of teaching is one from emphasis primarily on transmission of specific items of knowledge that may soon become obsolete, to one with emphasis on the intellectual skills that are applicable to a broad and largely unforeseen repertoire of task situations [2, 3]. Such education should have cognitive outcomes, equipping the students with the skills of logical thinking, critical analysis, decision making and above all an integrated view of knowledge—needs that have not been fulfilled by the traditional education system [4].

Evaluation system in the new pedagogy would call for extensive examination reforms which now need to be oriented towards measuring skills of application of knowledge [5]. It is the synthesis of these observations that has led to the concept of an exploratory teaching–learning which would answer the needs of future educational pedagogy, changing technology and society.

POLYTECHNIC EDUCATION AND PEDAGOGIC ISSUES CONCERNING POLYTECHNICS

Technical education in India operates at three levels, namely industrial training institutes offering certificate courses; polytechnics offering diploma courses; and engineering colleges and technical universities offering degree and post-degree courses. Polytechnics produce middle-level technical manpower for occupying various functional positions in industry. Polytechnic education in India was designed to offer generalized courses, such as diplomas in civil, mechanical and electrical engineering, which satisfied the initial needs of the country for basic infrastructure development for transport, power generation, etc. [6].

Scientific developments, the emergence of new areas of technology and increasing economic activity in India have led to rapid industrialization and consequent adoption of modern processes and practices. In this changed context, what Indian industries, employers and society expect from the products of polytechnics are the possession of specific knowledge and skills, and the ability to apply such knowledge and skills in new situations, and to learn skills and become responsive to changing needs [3, 4].

The design of the polytechnic education system and the type of courses offered since independence, however, have remained unchanged, resulting in criticism from the employers about the

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products of the polytechnics [7]. The salient pedagogic issues facing the polytechnics at present are:

1. Developing curricula that will meet the functional requirements of polytechnic products in industry.
2. Evolving an approach to teacher development to enable them to play the role of agents for change.
3. Preparing and making available teaching–learning material appropriate to the needs of students.
4. Developing an examination system that will evaluate students on their problem-solving abilities and total personality traits.
5. Providing opportunities for students for self-development so as to contribute effectively to society's needs.
6. Developing a management system in technical education that will encourage and support innovations in teaching–learning.

APPROACHES TOWARDS RESOLVING THE PEDAGOGIC ISSUES FACING THE POLYTECHNICS

From an analysis of the requirements of the world of work and the existing teacher-centred traditional system of curriculum offerings being practised in the polytechnics today [2, 3], what clearly emerges is that the existing method of technical human resource development would not help resolve the issues. Efforts to bring qualitative improvements in the system keeping the basic design by and large the same have yielded marginal benefits [8]. The requirement is, therefore, to design a teaching–learning system that will force a change in the long-established system of teaching–learning in the polytechnics.

All the pedagogic issues stated earlier call for evolving a new teaching–learning system focused primarily on the development of problem-solving abilities in students. Such a system will essentially be oriented towards developing cognitive abilities by having students face a variety of open-ended problem situations while pursuing their studies.

The above could be achieved through the following two approaches:

- Introducing education–work linkages as an integral part of curriculum design.
- Introducing the transfer of learning objectives in the teaching–learning process.

The first approach envisages opportunities for developing problem-solving competence through work experience in real-life situations, while the second contemplates similar opportunities in the institutional setting but through linkage with the world of work.

PLANNING FOR INTERACTIVE TEACHING–LEARNING SYSTEMS

Planning for developing teaching–learning systems, as envisaged in this study, is aimed at creating opportunities for the learner to engage in purposeful learning activities by establishing interactive relationships between him/her, the teacher and the employer. The following four conceptual models are envisaged for this study:

Industrial attachment of students for problem-solving experience

This model envisages institutional training of students through laboratory and classroom interactions around the prescribed curriculum, followed by attachment of students and their teachers to industries in small groups with specific problem assignments identified by the sponsoring industries. Each group of students, under the guidance of their teacher, would work for the solution of real-life problems. Industrial experts would be available for consultations and also for evaluating the students. In this circumstance a mutually beneficial and interactive triangular relationship is established between the students, the teacher and the industries. The possible advantages are that the students will get an opportunity for real-life problem-solving experience, the teacher will find the task of guiding students challenging and motivating and could become a future consultant for industrial problem solving, and industry would gain by getting solutions to their problems, as well as preparing better technical manpower for their future use. The evaluation of students would be done by the teachers and industry using multiple evaluation instruments to assess acquisition of problem-solving abilities and to provide feedback.

Open-ended, project-based student–teacher involvement as an integral part of classroom teaching–learning

This model envisages open-ended problem solving as project work while pursuing the subject in the classroom. A problem bank created from the environment would form the source of project assignments to students. Interaction with the sponsoring agencies of projects would be in the form of students visiting work-places for collection of basic data, the delivery of subject-related extension lectures by industrial experts, followed by group discussion, and evaluation of students' work and provision of feedback. The teacher will, in addition to teaching the subject content, have the responsibility of guiding the students in their project activities.

Institution-based self-learning through teacher-developed graded exercises/tasks

In this model graded exercises/tasks prepared around the course content would form the instructional material for the students to work on. The exercises/tasks would enable students work at their own pace of learning, interact with their teachers, and receive feedback. Periodic group discussion and enrichment lectures by the teachers would provide the opportunity for students to interact meaningfully with the teachers as well as amongst themselves. Evaluation of students would be done by suitable industrial experts and teachers, who would assess students' achievements and provide feedback.

Students' attachment for project activity in functional areas in relevant industries

This model envisages acquisition of basic knowledge and skills of a functional curriculum through institutional training, followed by attachment to relevant industries to work as 'interns' under the guidance of an industrial supervisor to gain real-life problem-solving experience. Related learning reference material provided to students would help them strengthen their understanding of the subject while assisting the supervisor in his or her tasks. Figure 1 shows the above conceptual models.

CONDUCT OF THE EXPERIMENTS

Experiments were conducted according to each of the models, the details of which are given in Table 1. In experiments 1 and 4 the placement of students in industries were made such that the students could travel daily from their normal places of residence. Industries in Experiment 2 were situated in the neighbourhood of the polytechnics. The selection of polytechnics, the students and teachers was made on a voluntary basis. Out of over 100 industries contacted, 70 agreed to collaborate. However, only 62 industries could actually be involved. The students in experiment 1 belonged to the discipline of civil, mechanical and electrical and architectural assistantship, while for experiments 2–4 the students were of electrical engineering discipline. The subjects of study in experiments 2–4 were electrical design, estimating and costing, electrical drawing, and electrical machines respectively. In experiments 1–3 the existing curriculum was used for instruction. For

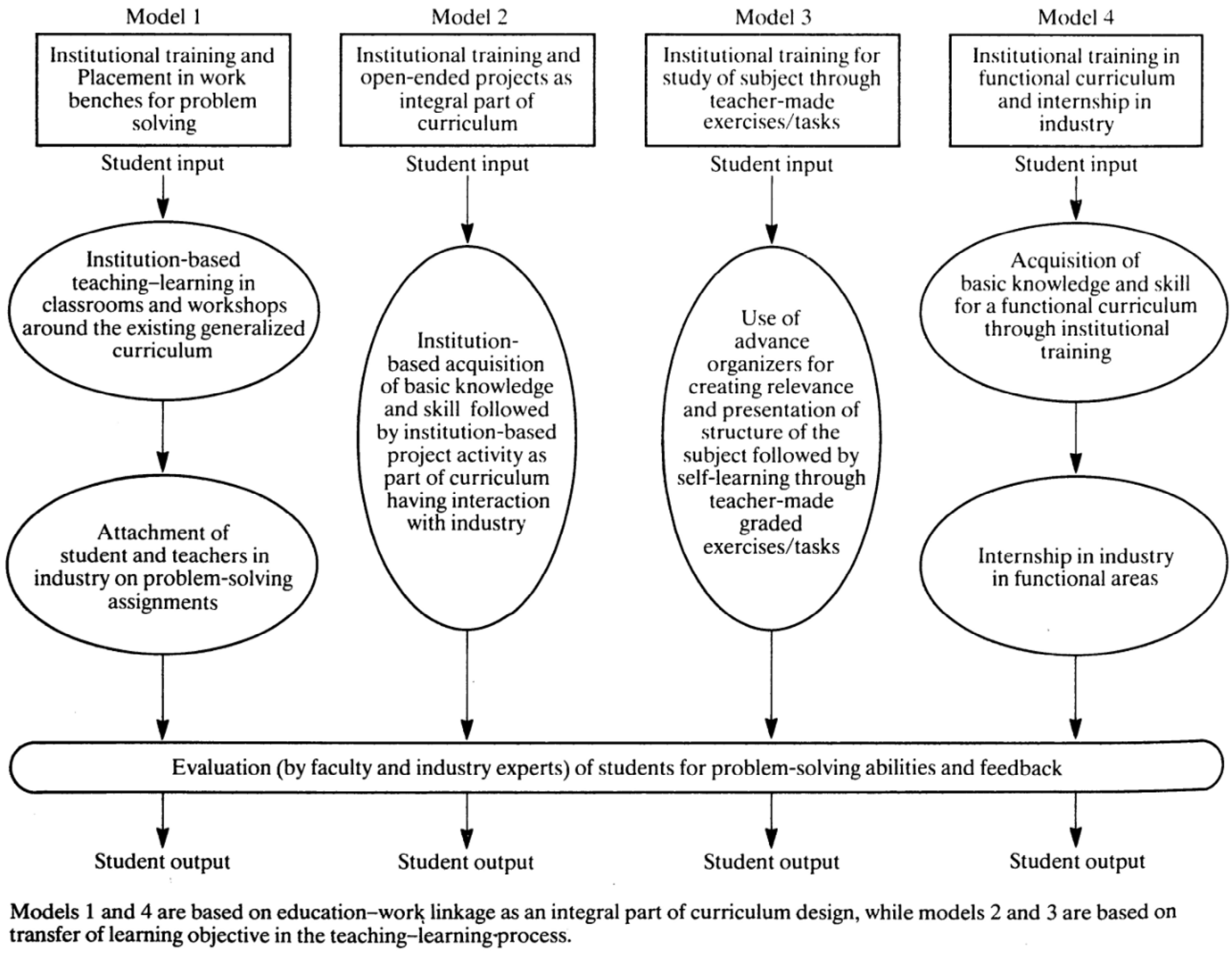

Fig. 1 Four conceptual models for developing problem-solving abilities in students. Models 1 and 4 are based on education–work linkage as an integral part of curriculum design, while models 2 and 3 are based on transfer of learning objective in the teaching–learning process.

Table 1. Details of the experiments conducted using different models

	Model 1	Model 2	Model 3	Model 4
Number of polytechnics involved	4	1	1	1
Number of students involved	85	132	42	13
Number of industries involved	35	22	2	3
Number of teachers involved	17	6	2	2
Duration of conduct of the experiments	8 weeks	3 sem[a]	1 sem	8 weeks

[a] sem = semester (1 semester = 16 weeks).

experiment 4 a functional curriculum and the required course material were developed through task analysis in seven related industries. Evaluation of students was made jointly by the teacher and industrial expert through multiple objective evaluation instruments. The evaluation instruments were aimed at judging the students' abilities in terms of knowledge of concepts and their applications, intellectual ability, creativeness and originality in conceiving new ideas and suggesting suitable solutions to problems, professional judgement, documentation and self-study, self-expression, initiative in learning, and self-reliance. There was full-time teacher involvement in experiments 1–3, while in experiment 4 a teacher helped students develop basic knowledge and skill through institutional training and visited the students in industry twice a week to participate in group discussions and student evaluations.

EXPERIMENTAL RESULTS

The results of the experiments were recorded on the basis of students' achievements and their reactions, industries' response, and feedback from teachers. The results are stated in terms of major outcome and requirements.

Experiment 1: open-ended projects at work-bench
(A) Outcome

1. 80% of the students could complete the projects to the satisfaction of industry in the stipulated time.
2. All students learned the approach to open-ended problem solving.
3. All industries showed willingness to receive students on a regular basis.
4. Improved behavioural response observed in all the students.
5. 94% of teachers expressed their preference of the new pedagogy over the prevailing method.

(B) Requirements

1. Both industry and students stressed that the full-time involvement of a teacher in project guidance was essential.
2. Polytechnic curricula need revision based on field requirements.
3. Polytechnics need to plan for involvement of a large number of industries so as to accommodate all the students.
4. Polytechnics need to prepare a 'problem bank' by consulting industries, prepare profiles of students and place students in industry according to industries' requirements and students' interest.

Experiment 2: open-ended projects as an integral part of curriculum
(A) Outcome

1. Project output of use to all the collaborating industries.
2. Skill development and also better understanding of subject as indicated by improved learner performance in the examination conducted by Board of Technical Education (the diploma-awarding authority).

(B) Requirements

1. Need for establishing linkage with industry.
2. Teachers need to have periodic attachment to industry in order to keep up to date with technological developments so that they can effectively guide students in their project activities.

Experiment 3: Use of teacher-made graded exercises/tasks in classroom instruction
(A) Outcome

1. Improved student performance in examinations conducted by Board of Technical Education.
2. Improved overall motivation of the class towards learning.
3. Performance of students in evaluation for transfer of learning only satisfactory.
4. Poor correlation of students' score in examinations conducted by the Board of Technical Education and the scores obtained in problem solving.
5. Performance of students belonging to upper group (classified according to academic track record at the entry level) has been better than the lower group.

(B) Requirements

1. Graded exercises/tasks need to have similarity with real-life problems.
2. Teachers need to involve industry in preparation of exercises/tasks.
3. Need for curriculum revision as per field practices.

Experiment 4: Student attachment in functional areas in industries

(A) Outcome

1. Both industries and students found curriculum relevant to the needs of students.
2. Industry found students a help rather than a burden.
3. Improved student motivation in learning was observed.
4. Better learning of subject matter as students performed better as compared to students taught only through institutional-based, teacher-centred learning.
5. Students who underwent this experiment showed better performance in terms of understanding of the subject as well as in terms of criterion of selection of students by industry for employment.
6. 35% of the content of the existing curriculum could be deleted from the institutional training requirement.
7. Internship in one functional area equipped students with practical skills to take up assignments in other functional areas. Relative time taken by students for functional mobility was less as compared to time taken by students who have only gone through institutional training.
8. Polytechnics needed facilities in laboratories and workshops for development of basic skills only, thereby reducing the cost of infrastructure requirement.

(B) Requirements

1. Polytechnics need to put extra effort to develop functional curriculum with the involvement of employers.
2. Teachers need to develop students' reference material for use in industry.
3. Polytechnics need to plan student attachment in related industries and monitor progress through faculty visits.

CHOICE OF MODELS IN TERMS OF THE PEDAGOGIC ISSUES

Model 4 answers all the pedagogic issues in terms of curriculum requirement, learner opportunities, instructional material requirement and evaluation of students. However, the management have to put in extra effort by involving the faculty in developing a functional curriculum and students' reference material by interacting with industry, and to find places of internship for students in industry as well as monitoring students' progress. Thus the take off time for implementing this model is quite high.

Model 1 answers the needs of all the issues except the curriculum requirement and planning on the part of polytechnic for student and faculty attachment in industries as part of the curriculum requirement.

Both models 1 and 4 can be implemented without increasing the total duration of polytechnic courses as certain institutional efforts in terms of the curricula may be dispensed with and these resources shifted to periods spent by students in industry. This gives better results and at the same time optimizes the infrastructure developmental requirement within the institute.

Model 2 responds to all the pedagogic issues except that it involves a heavy demand on teacher preparation in terms of equipping them with knowledge of technological developments in industry and establishing linkages with the environment for developing and updating a problem bank. With such an effort it is also possible, with the help of teachers, to implement required changes in the existing curricula.

Model 3 has limitations inherent in the design as the exercises or tasks are only real-life like in nature. This experience is inferior to the real-life experience available in the other three models. Design and development of exercises demands that teachers devote time to preparatory work. The quality of experience, its transfer value, and students' motivation will depend greatly on the quality of the assignments and tasks formulated by the teacher.

The involvement of industries in curriculum revision and in preparation of exercises/tasks would improve the transfer value of such exercises and tasks unless the teachers themselves are a blend of curriculum developers and industrial managers.

Models 1, 2 and 4 offer the possibility of students receiving monetary incentives while pursuing studies in polytechnics (35% of students received monetary incentives and others received letters of appreciation from industry in the experimental study). Models 1 and 4 have the added advantage over models 2 and 3 in the sense that they bring students in close contact with industries, provide opportunities for students to get employment by demonstrating their abilities, and help industries observe students closely over a period of time and make employment selection in their own organization.

Models 1 and 4 are therefore recommended to be used for curriculum implementation of the final year of the diploma course, while models 2 and 3 are recommended for curriculum implementation of the first and second year, where students could be prepared for their performance in problem solving when placed in industry and thereby derive monetary incentives as well as get employment assurance.

CONCLUSION

Decreasing student motivation in learning, employer dissatisfaction in the quality of output of technical institutes, teachers finding their job devoid of much challenge, and increasing resource constraints on expanding institutional infrastructure development, demand evolving innovative systems of teaching–learning that will respond to the requirements of employers and the aspirations of students.

The models described in this paper are some of the alternatives to the existing teacher-centred purely institutional-based teaching–learning being carried out in most of the institutions in India and elsewhere.

A flexible approach on the part of managements in encouraging constant innovations in teaching–learning will hopefully bring an atmosphere of change within the system and thus develop a curriculum process that can respond to the needs of society *vis-à-vis* the students.

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