Adopting An Action-Learning Approach to Teach Industrial Engineering Courses in Universities: The UWI Experience

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Action-learning involves "learning about learning" that enables people to handle dynamic problems. This paper reviews the concept of action-learning and discusses the adoption of an action-learning approach in teaching Industrial Engineering courses at universities. It presents the experience of The University of the West Indies (UWI), Trinidad in the design and delivery of an action-based teaching course. The course incorporates formal lectures, tutorials and an outdoor workshop that has been implemented with encouraging results in student learning and development. This paper concludes by underlining that action-based teaching stresses teamwork and experiential learning principles, and is an effective means other than the traditional classroom and IT-oriented teaching in universities.

Keywords: Action-based teaching, action learning, industrial engineering.

1. Introduction

The competitive pressures in the global markets have been complicated with the emergence of international competitors and applications of new technologies in design, manufacturing and management. Industrial engineering (IE) is one of the most people-oriented and customer-focused engineering disciplines. It integrates knowledge and skills from several fields of science such as the technical sciences, economic sciences and human science; and all these can also be supported with skills in information sciences [1]. IE is concerned with the analysis, design and optimisation of integrated industrial systems that stress product and process innovation, manufacturing/operations improvement and enterprise development. Industrial systems are composed of manufacturing and service-oriented systems and include a broad scope of industries consistent with an integrated approach of IE [1,2].

There is no easy, turnkey solution for many problems related to integrating cross-functional operations, making timely decisions and managing contingencies in a dynamic environment. Traditionally, marketing and operations people would identify product developments and features at the beginning and then ensure that engineers do not deviate from specifications. This view sounds sensible but has serious practical limitations. For instance, some recent studies (e.g., [3,4]) found that an engineer would not hypothetically forward a design to be implemented by production without considering manufacturing capability and capacity. Many production organisations are increasingly relying on good engineering practices in general and IE skills and knowledge in particular to gain and sustain their competitiveness.

Contemporary changes in industry demand have resulted in the emergence and increase in engineering education. Practice-oriented Master's degree and professional engineering programmes have attracted the interests of industrial professionals [5,6]. Many studies (e.g., [4,5]) also found that relying solely on traditional classroom teaching would not meet new challenges and rapid changes in engineering education. There is a pressing need to broaden teaching approaches, design new courses and re-design current curriculums to meet the changes. Incorporating action-

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learning principles into teaching is an effective means of maintaining a balance between theory and practice [4,9]. Action-based teaching (ABT) is built upon the concept of action-learning that involves working on problems, focusing on learning and implementing solutions [7,8]. This paper presents a case of adopting action-learning principles to teach industrial engineering courses at The University of the West Indies (UWI), Trinidad. The effectiveness of ABT is discussed along with an analysis of student performance assessment and learning outcomes.

2. The Concept of Action-Learning

The traditional and enduring view of learning has assumed that knowledge must be transmitted and received in the form of information, theories and research findings and after reception, learners can apply the knowledge to their own purposes [10]. In contrast to this, action-learning is learning from concrete experience and critical reflection on that experience – through group discussion, trial and error, discovery and learning from and with one another [8,10]. **Passfield** [11] argues that action-learning is a process of collaborative transformation in which members of a social system transform themselves and their social system through participative reflection-in-action. **Zuber-Skerritt** [10] regards it as a process by which groups of people (students or learners generally) address actual workplace issues or problems, in complex situations and conditions.

Action-learning involves learning about learning and is individual, social and job-related [7,10]. It is not only self-aware but also to some extent self-interest, since learners themselves have a vested interest in the outcome. It provides a flexible and systematic method to conceptualise learning from experience. Action-learning is concrete and concerned with learners' actual experiences, therefore it is immediately relevant to their practical work [7,8]. Action-learning can be used to great advantage when no one knows the solution to a shared problem, or when no one knows the way forward in a complex situation. **Revans** [7,8] regarded this as an approach based on the premise that there is no learning without action and no sober and deliberate action without learning.

Nevertheless, action-learning would be considered inappropriate when answers are straightforward, already known, or can be found more simply, cheaply and quickly (e.g., by computer programmes) [10]. Besides, some shortcomings evident in the typical practice of action- learning in inappropriate circumstances. These include:-

1) Lack of a system in strategic framing;
2) Problem-structuring, problem-solving and learning processes founded narrowly on the scientific method without regard for tools and methods which are now available; and
3) Lack of routine explicit exploration of mindsets and other 'soft' factors important to personal development [12].

3. Action-Learning Approach To Teaching

Teaching Engineering courses at universities is a highly significant task and requires supervision, guidance and instruction [13]. This is a complex educational process involving technical elements (e.g., equipment, technology and materials) and managerial elements (e.g., human resources, planning and costing). A major difficulty is how best to address the complexity inherent in teaching the subject. Many universities and academic institutions have recognised a pressing need to deliver new Engineering courses and/or re-design current curriculums [6]. Changing a traditional classroom teaching into an action-learning approach could be beneficial to the students [4,14].

According to **Zuber-Skerritt** [10], action-learning programmes always come up with various common elements, including learning by doing; experiential learning; reflecting on practice; being open; sharing ideas; collaborating; learning to learn; life-long learning; and learning in the workplace. Adopting action-learning approach to teaching, or in short 'action-based teaching' could bring these elements together in one approach, leveraging the synergy thus produced. The ABT approach stresses teamwork and experiential learning principles to accomplish common goals [10]. It incorporates process- and results-oriented evaluation and also encourages creativity that helps students to increase their confidence and liberate new thoughts and ideas [4]. This provides potential for universities and institutions to integrate theories and practices better in their programmes [15]. Adopting ABT could bring students together to find solutions to problems and, in doing so, development both individuals and the teams.

4. Core Components of Action-Based Teaching

4.1 *Teamwork and Team-building*

Teamwork is an essential component in the concept of action-learning [10] and is important in many contexts for improved teaching and learning performance by providing a satisfying, stimulating and enjoyable learning environment [4]. For team members (or students) to work and learn cooperatively, there must be a network of personal relationships linking them. Teams are purpose-driven. **Mazany *et al.*** [16] argue that team development should not disguise the fact that a team contains individuals. Effective teams would demonstrate synergy, i.e., the team is greater than the sum of the parts.

Moreover, effective teams would have a clear, worthwhile and challenging mission to which all members are committed. This would in turn rely significantly on effective team-building and development [4,16]. Team-building and development would help a team to speed through the stage to becoming a high-performing team, via stages of '*forming*', '*storming*', '*norming*', '*performing*' and '*reforming*' [16]. Based on the study of **Barczak & Wilemon** [17], six key factors are identified and refined as drivers of team member satisfaction. These factors include:

- Team characteristics,
- Clear teaching and learning goals,
- Clarity about evaluation and rewards,
- Effective leadership,
- Facilitation and support, and
- Manageable levels of conflicts and stress.

4.2 *Questioning Insight and Creativity*

According to **Revans** [7,8], learning is programmed knowledge (i.e., routine knowledge in use) plus questioning insight. Programmed knowledge must be expanded and be supplemented by questioning insight that is the capacity to identify useful and fresh lines of enquiry. Action-learning is about real people (students) tackling problems in real time. It is not learning from experts, case studies and simulations but, from and with one another in a workplace [10]. Through participation in experiential learning activities (e.g., games, outdoor workshops, and skill and challenge activities, etc), students characteristically act in a similar manner to how they act at work. Competition, cooperation, domination, ethics and safety can all be discussed with specific reference to the activity as a metaphor for normal work circumstances. In this manner, students can learn from their own and other's behaviour in more positive, fun and less incriminatory constructive way [16].

On the other hand, creativity is grounded in the experiential principles of action-learning. It focuses on the nature of thought processes and intellectual activity used to generate new insights or solutions to problems [18]. The action-based teaching can flourish an action-learning environment that encourages creativity of individuals and groups [4]. The patterns of interaction among people, roles, technology and the external environment are often complex. The value, norms and beliefs can either support or inhibit creativity, depending on how they influence the behaviour of individuals and groups [18].

4.3 *Process and Results-oriented*

When designing experiential learning activities, the needs of the participants (students) should be considered. Planning is an essential element in these activities. The better-planned and integrated is an experiential learning event or course, the more likely it is to have a long-term effect on student-learning [16].

Many authors (e.g., see [19,20]) cite cases of a particular learning programme in action or suggest 'to do' lists to ensure success or minimise failure. Some others suggest some forms of quantitative and qualitative measures and composite measures (e.g., fewer political dilemmas, better planning and improved team members' confidence) [16]. Action-based teaching stresses both process- and results-oriented evaluation for establishing the effectiveness of student learning [4]. This is about the learning that arises from the process linked to the solutions to problem(s) [4,7]. The development of a solution would draw on the skills of identifying and analysing experience, reflection and feedback.

5. A Case of Action-Based

Teaching at UWI

The Department of Mechanical and Manufacturing Engineering at UWI has since 2001 adopted action-learning concepts in the design and delivery of some of its industrial engineering courses. Typical courses include Project Management and Production Planning and Control that have incorporated experiential learning components. Outdoor action-learning workshops, like 'PAPLANE-II' [4] and 'Build a Tower' [21] have been successfully implemented several times with encouraging results in student learning and development in the university. In order to demonstrate the versatility of action-based teaching, the following section presents a case addressing the learning objectives, the design and delivery of an action-learning workshop for one of these courses in the Industrial Engineering Department at UWI.

5.1 Course Information

The Production Planning and Control (PPC) course is a core subject of a Bachelor of Science degree programme in Industrial Engineering at UWI. The course syllabus covers a broad area including production systems, forecasting, resources planning, aggregate planning, master schedule, requirements planning systems, scheduling, progress control and integrated production control systems [2]. Students taking that course are in their final year in the programme specialising in the engineering and production management stream. The class size is normally small and is less than 30 students. A teaching team normally includes a lecturer together with one or two tutors depending on the size of the class.

The PPC course lasts for one semester, consisting of lectures, tutorials and a PAPLANE-II workshop. Students will take a two-hour lecture and spend another one hour per week on tutorials and group activities for 13 weeks. The workshop is scheduled for the end of the course on the campus. The workshop is the experiential component and is a major part of the continuous assessment of the course. It is modified based on its precedent PAPLANE (stands for 'paper plane') workshop that was developed by City University of Hong Kong [4]. The course schedule and the descriptions of the workshop are depicted in **Table 1**.

5.2 Learning Objectives

In the PAPLANE-II workshop, students are asked to build their team and design and manufacture new products (i.e., paper planes) with respect to given specifications and constraints. They need to implement a production system that closely imitates the real world's competitive environment. The workshop has four learning objectives that facilitate students to:

- Understand the cross-functional operations in an organisation;
- Make timely decisions and manage contingencies in an uncertain environment;
- Experience team building and group decision-making; and
- Solve open-ended problems by 'developing skills through doing'.

5.3 Workshop Design and Delivery

The PAPLANE-II workshop can run with three or more participating teams and each team can have five to seven members depending on the number of students enrolled in the course.

For instance, a 20-student class can form four teams with a minimum size of five members per team, or three teams with six to seven students each. Participating teams will develop their organisational structure, formulate their product-mix strategies and set up a production line to produce paper planes [4].

Incorporating the team building processes, individual members may take self-initiatives or be assigned deliberately by facilitators with different roles and responsibilities such as leader, product designer, engineer, quality auditor, financial auditor, production personnel, negotiator, and observer in a team. This is an IE course on production planning and control. The design of the workshop serves to enhance the students' understanding and knowledge of production operations and practices. The workshop is composed of several phases, including design and prototyping, process-planning, bidding, contracting, materials purchasing and negotiating, production, flying test, profit calculations, summing up and presentation.

Participating teams will compete with one another for the champion or best-performed team. They need to develop a product-mix strategy and determine their maximum production capability in

TABLE 1: *Course Schedule and Descriptions of the Workshop*

Week	Activity Schedule and Phases	Preparation/Submission of Assignments	Highlights of Course/Workshop Contents
1	Introduction of the course and PAPLANE-II workshop	*Course briefing, rules and guidelines*	- Course structure and schedule - Self-assessment exercises
2-3	Team composition procedure	*Formation and development of teams* * Forming * Storing * Norming * Performing	- Individual 'Strengths-Weaknesses-Opportunities-Threats' (SWOT) analysis - Grouping of students - Group profile analysis - Meeting and report-writing skills
4-6	Production system design, product idea screening, planning and prototyping phases	*Submission of Task Report I* * Company mission, strategies and policies * Production system design * Product strategies and prototype design * Materials requirements and acquisition * Financial planning and budget	- Selection and assignment of individual tasks - Literature review and desk research on production/ operations areas and topics - Oral presentation of task I (10-15 mins. each) - Submission of task report I and feedback from members and facilitators
7-9	Production planning and scheduling phases	*Submission of task report II* * Capacity plan, production plan and schedule * Facility and process planning * Work and job design * Quality assurance and auditing	- Oral presentation of task II (10-15 mins. each) - Submission of task report II and feedback from members and facilitators - Preparation of bidding documents - Design of new products and making of prototypes
10-11	Bidding, contracting, material purchasing and negotiating phases	*Submisison of task report III* * Bidding strategies * Contract-making and negotiation * Material procurement	- Participating the close and open bidding exercises - Preparation of contracts and purchasing orders - Preparation of contingency plan - Planning and scheduling for the production
12-13	The PAPLANE-II workshop (Production, flying test, profit calculations and presentation phases)	*Submission of final repot* * Individual files * Group files	- 15 mins. of production - Flying test, product audit and profit calculations - Coaching and peer evaluation - Oral presentation and submission of final report

15 minutes using four people. Three different types of paper planes are to be designed and these planes must meet three criteria, namely:

1) Able to fly for at least a linear distance of 10 metres,
2) Meet the minimum length of 20 cms, and
3) Have correct size and position of company logos.

Basic designs of paper planes with seven folds and nine folds are to be considered and their selling prices vary. A minimum of 10 planes for each type is needed to meet the minimum contractual requirements.

A host of factors including product design, product-mix and bidding strategies, the issues of quality and reliability, teamwork, and decision making, etc. would distinguish the performance among participating teams. The champion team would be the one with the highest after-sales profits potential,and demonstrate team performance with supporting evidence and documentation.

5.4 Workshop Assessment

The workshop adopts a performance-driven assessment scheme, as depicted in **Table 2.** The scheme stresses student participation and stimulates team efforts and results. One week after the game, each participating team needs to prepare a group file and an observer's report and members need to submit their own individual files for assessment purposes. The group file reports the teams' achievements obtained from the workshop, relating them to the formulation of strategy, product and process design, quality matters and financial analysis. The observer's report explains the teamwork and processes addressing the group structure, communication, leadership style, student participation and coordination. The individual files summarise the personal experience gained from the workshop.

A self and peer evaluation questionnaire/form is designed for facilitating the assessment of student learning and performance. Students are required to assess their personal achievements and evaluate other members' performance with respect to a list of 26 learning/evaluation elements in the questionnaire as listed in **Table 3.** Each element is evaluated based on a 10-point scale (i.e., 1 stands for 'strongly disagree' or 'extremely poor', whereas 10 stands for 'strongly agree' or 'extremely good'). The 25 elements are grouped into five dimensions of team functioning.

First of all, the leadership dimension (with seven elements) examines the appointment and style of team leader and whether the groups problems were solved individually or by consensus. It questions whether all the members are equally involved and the attention that some members might experience. Secondly, the communication dimension (with six elements) relates to the ability of the team to communicate ideas and opinions effectively, to give and to receive feedback and to reach sound conclusions. This also asks whether members were committed to the team and its solution.

The other three dimensions (totalling 12 elements) examine collectively the identification and analysis of problems, making decisions, and planning and scheduling solutions. They investigate how the team approaches the decision-making process and the method involved. They also ask how well the team achieves its task in the given time-frame, how efficiently the team planned and solved the problem, and looked at the quality of the output.

TABLE 2: *A Performance-driven Assessment Scheme*

Assessment Items		Individual	Group
Attendance		10%	-
Individual Performance in Team		10%	-
Presentation	• Interim Task Progress	10%	-
	• Workshop	-	20%
Reports	• Individual File	20%	-
	• Group File	-	30%
		50%	50%
	Total:	100%	

TABLE 3: *Learning Elements in Self and Peer Evaluation*

Dimensions/Categories		Learning/Evaluation Elements
Leadership	L1.	Able to provide team direction.
	L2.	Commits to group solution and assumptions.
	L3.	Able to make or shape plans.
	L4.	Able to schedule team activities.
	L5.	Receptive to ideas generated from others.
	L6.	Willing to give feedback to others.
	L7.	Able to facilitate the group decision process.
Communication	C8.	Able to communicate ideas, information and plans.
	C9.	Willing to share and exchanges information.
	C10.	Able to acquire presentational skills.
	C11.	Able to listen to ideas, thouhts and facts from others.
	C12.	Able to write in a logical and clear manner.
	C13.	Rank not inhibiting idea flows.
Identification and Analysis of Problems	I14.	Recognises problem situations and identifies underlying issues.
	I15.	Collects relevant information to analyse problems.
	I16.	Generates alternative solutions to problems.
	I17.	Analyses factors affecting the selection of solutions.
	I18.	Analyses solution options and makes changes if needed.
Making Decisions	M19.	Able to voice our opinions on making decisions.
	M20.	Works together as a team.
	M21.	Identifies appropriate solutions to problems.
	M22.	Evaluates potential problems or risks of solutions.
Planning and Scheduling Solutions	P23.	Schedules solutions with respect to priorities, workload and time.
	P24.	Plans and organises resources to make thing done.
	P25.	Monitors the effectiveness of solutions.

6. Evaluation of Student-Learning Performance

6.1 Self vs. Peer Evaluation

In order to illustrate how ABT could attain student-learning performance, the 2002 Industrial Engineering class in the PPC course at UWI was based upon. A group of 16 students enrolled in the course and three participating teams (i.e., Team 1, Team 2 and Team 3) were formed. Team 1 was the champion team with the best performance while another two were challenging teams. A post-workshop assessment of students' learning performance was made using a self and peer evaluation questionnaire, and the findings were analysed with an aid of a statistical software.

Tables 4, 5 and **6** show the self vs. peer evaluations on learning performance of the leaders of three teams, respectively. It was found that the Team-1 leader attained an overall self-evaluation score of 198 out of 250. The self-evaluation scores of the leaders of Teams 2 and 3 were 181 and 188, respectively. The self-evaluation scores of Team-1 and 2 leaders were coincided with their peers' weighted scores (i.e., 199.8 and 180.5, respectively out of 250). Nevertheless, the Team-3 leader's self-evaluation score was slightly higher than the peers' weighted score.

TABLE 4: *Self vs. Peer Evaluations of Team-1 Leader Performance*

Evaluation Elements[1]	Self Score[2] (A)	Peer[2] 1	Peer[2] 2	Peer[2] 3	Peer[2] 4	Peer[2] 5	Peer Score Mean[2] (B)	Peer Score SD[3]	Self-Peer Score Difference (A-B)
L-1	6	6	10	8	7	8	7.80	1.48	-1.80
L-2	7	7	9	8	8	8	8.00	0.71	-1.00
L-3	6	7	9	8	6	8	7.60	1.14	-1.60
L-4	5	3	9	9	6	6	6.60	2.51	-1.60
L-5	8	7	10	9	8	8	8.40	1.14	-0.40
L-6	9	7	10	9	8	8	8.40	1.14	0.60
L-7	9	6	10	9	8	8	8.20	1.48	0.80
C-8	9	6	10	8	8	9	8.20	1.48	0.80
C-9	8	8	10	10	8	8	8.80	1.10	-0.80
C-10	8	5	5	8	8	8	6.80	1.64	1.20
C-11	10	9	10	10	9	8	9.20	0.84	0.80
C-12	8	5	4	8	8	6	6.20	1.79	1.80
C-13	9	9	10	10	8	6	8.60	1.67	0.40
I-14	8	9	10	10	8	6	8.60	1.67	-0.60
I-15	8	7	10	10	8	7	8.40	1.52	-0.40
I-16	9	7	10	10	8	8	8.60	1.34	0.40
I-17	10	10	10	9	9	8	9.20	0.84	0.80
I-18	9	10	10	9	8	8	9.00	1.00	0.00
M-19	8	7	10	7	8	8	8.00	1.22	0.00
M-20	9	7	10	8	9	8	8.40	1.14	0.60
M-21	8	8	8	8	8	8	8.00	0.00	0.00
M-22	6	7	9	9	7	6	7.60	1.34	-1.60
P-23	7	6	9	3	8	6	6.40	2.30	0.60
P-24	7	6	10	4	8	8	7.20	2.28	-0.20
P-25	7	7	10	5	8	8	7.60	1.82	-0.60
Total Score:	198	176	232	206	197	188	199.80		

Notes:

1 – The categories of evaluation elements are L: Leadership; C: Communication; I: Identification and analysis of problems; M: Making decisions; P: Planning and scheduling solutions
(For a brief description of evaluation elements, see **Table 3**).

2 – A '10-point' scale is used, i.e., 1 = Strongly disagree or Extremely poor; 10 = Strongly agree or Extremely good.

3 – SD = Standard Deviation.

TABLE 5: *Self vs. Peer Evaluations of Team-2 Leader Performance*

Evaluation Elements[1]	Self Score[2] (A)	Peer[2] 1	Peer[2] 2	Peer[2] 3	Peer[2] 4	Peer Score Mean[2] (B)	Peer Score SD[3]	Self-Peer Score Difference (A-B)
L-1	8	8	6	8	7	7.25	0.96	0.75
L-2	7	8	8	8	8	8.00	0.00	-1.00
L-3	7	8	8	8	6	7.50	1.00	-0.50
L-4	7	9	10	6	7	8.00	1.83	-1.00
L-5	9	10	10	8	6	8.50	1.91	0.50
L-6	7	9	8	8	7	8.00	0.82	-1.00
L-7	8	9	8	8	7	8.00	0.82	0.00
C-8	8	8	5	9	6	7.00	1.83	1.00
C-9	8	9	5	8	6	7.00	1.83	1.00
C-10	7	8	7	8	8	7.75	0.50	-0.75
C-11	7	9	7	8	5	7.25	1.71	-0.25
C-12	7	8	7	6	9	7.50	1.29	-0.50
C-13	5	5	5	6	5	5.25	0.50	-0.25
I-14	8	7	5	6	9	6.75	1.71	1.25
I-15	6	8	5	7	9	7.25	1.71	-1.25
I-16	7	8	7	8	7	7.50	0.58	-0.50
I-17	7	3	7	8	7	6.25	2.22	0.75
I-18	8	8	6	8	10	8.00	1.63	0.00
M-19	7	8	7	8	10	8.25	1.26	-1.25
M-20	7	5	4	8	7	6.00	1.83	1.00
M-21	7	6	6	8	7	6.75	0.96	0.25
M-22	8	7	8	6	8	7.25	0.96	0.75
P-23	7	5	7	6	6	6.00	0.82	1.00
P-24	7	7	5	8	6	6.50	1.29	0.50
P-25	7	7	6	8	7	7.00	0.82	0.00
Total Score:	181	187	167	188	180	180.50		

Notes:

1 – The categories of evaluation elements are L: Leadership; C: Communication; I: Identification and analysis of problems; M: Making decisions; P: Planning and scheduling solutions
(For a brief description of evaluation elements, see **Table 3**).

2 – A '10-point' scale is used, i.e., 1 = Strongly disagree or Extremely poor; 10 = Strongly agree or Extremely good.

3 – SD = Standard Deviation.

TABLE 6: *Self vs. Peer Evaluations of Team-3 Leader Performance*

Evaluation Elements[1]	Self Score[2] (A)	Peer[2] 1	Peer[2] 2	Peer[2] 3	Peer[2] 4	Peer Score Mean[2] (B)	Peer Score SD[3]	Self-Peer Score Difference (A-B)
L-1	6	3	7	7	6	5.75	1.89	0.25
L-2	7	4	9	8	8	7.25	2.22	-0.25
L-3	8	5	8	8	7	7.00	1.41	1.00
L-4	6	4	9	5	8	6.50	2.38	-0.50
L-5	9	6	10	8	10	8.50	1.91	0.50
L-6	8	6	10	8	10	8.50	1.91	-0.50
L-7	9	5	9	9	8	7.75	1.89	1.25
C-8	6	8	9	7	8	8.00	0.82	-2.00
C-9	7	7	9	8	6	7.50	1.29	-0.50
C-10	5	7	8	6	6	6.75	0.96	-1.75
C-11	8	5	9	8	7	7.25	1.71	0.75
C-12	10	8	9	9	7	8.25	0.96	1.75
C-13	9	9	9	9	7	8.50	1.00	0.50
I-14	8	7	9	9	6	7.75	1.50	0.25
I-15	5	5	8	5	6	6.00	1.41	-1.00
I-16	7	7	7	8	6	7.00	0.82	0.00
I-17	5	7	9	6	7	7.25	1.26	-2.25
I-18	8	7	9	8	7	7.75	0.96	0.25
M-19	10	8	10	9	6	8.25	1.71	1.75
M-20	10	10	8	9	7	8.50	1.29	1.50
M-21	9	5	8	9	5	6.75	2.06	2.25
M-22	9	5	8	9	4	6.50	2.38	2.50
P-23	5	8	9	5	6	7.00	1.83	-2.00
P-24	5	7	8	5	7	6.75	1.26	-1.75
P-25	9	7	8	9	7	7.75	0.96	1.25
Total Score:	188	160	216	191	172	184.75		

Notes:

1 – The categories of evaluation elements are L: Leadership; C: Communication; I: Identification and analysis of problems; M: Making decisions; P: Planning and scheduling solutions
(For a brief description of evaluation elements, see **Table 3**).

2 – A '10-point' scale is used, i.e., 1 = Strongly disagree or Extremely poor; 10 = Strongly agree or Extremely good.

3 – SD = Standard Deviation.

This implies that there were different views between the team leader and members on evaluating his/her performance.

While examining the standard deviations (SD) of peer scores and the differences in self-peer scores among 25 evaluation elements, there were some outstanding differences among three teams. For the evaluation records of Team 1, SD of peer scores ranged from 0 to 2.51, whereas that for Team 2 and Team 3 ranged from 0 to 2.22 and from 0.82 to 2.38, respectively. The differences of self-peer scores ranged from -1.80 to 1.80 in Team 1, -1.25 to 1.25 in Team 2 and -2.25 to 2.50 in Team 3, respectively. The variations of self vs. peer evaluations of Team 3 leader's performance were also greater as compared to that of Teams 1 and 2.

The performance results showed that Team-1 leader generally performed better than leaders of the two other challenging teams in the five dimensions of evaluation. While assessing individual dimensions in each team, Team-1 leader was rated strong in many elements of leadership, communication, and identification and analysis of problems (see **Table 4**). In particular, the student was receptive to ideas generated from others (Mean score = 8.4), willing to give feedback to others (Mean score = 8.4), and share and exchange information with other members (Mean score = 8.8). The student also performed well in ranking ideas (Mean score = 8.6), analysing factors that affect the selection of solutions (Mean score = 9.2) and analysing solution options (Mean score = 9.0). However, the student was comparatively weak in planning and scheduling solution; particularly in scheduling solutions with consideration of priorities, workload and time (Mean score = 6.4).

Team-2 leader was comparatively strong in some elements of leadership and making decisions (see **Table 5**). The student was receptive to ideas generated from team members (Mean score = 8.5) and able to voice out opinions on making decisions (Mean score = 8.25). However, the student was weak in some elements of communication and planning and scheduling solution. In particular, the student has critique on inhibiting idea flows (Mean score = 5.25) and could not schedule solutions considering priorities, workload and time (Mean score = 6.0).

Lastly, Team-3 leader performed well in some elements of leadership, communication and making decisions (see **Table 6**). These included 'Receptive to ideas generated from others' (Mean score = 8.5); 'Willing to give feedback to others' (Mean score = 8.5); 'Able to write in a logical and clear manner' (Mean score = 8.25); 'Rank not inhibiting idea flows' (Mean score = 8.5); 'Able to voice out opinions on making decisions' (Mean score = 8.25); and 'Worked together as a team' (Mean score = 8.5). However, the student was comparatively weak in identification and analysis of problems particularly in collecting relevant information (Mean-score = 6.0). Results showed that team leaders were taking influential roles in safeguarding the success of teams and the ABT process.

Analysis on learning performance results of individual members in each team would have been made in the same fashion. It is a critical step in applying the experiential learning experience to foster generative learning, and incorporating a debriefing of performance results that allows participants to analyse and reflect on their efforts to solve the problem as a team [19]. The evaluation exercise helps individuals and teams to understand their strengths and identify their weaknesses objectively and collectively [4, 21].

6.2 Facilitators' Assessments

Conducting experiential learning, or more specifically, ABT workshops could be valuable in team-building, morale, communication, understanding and providing effective learning for the students. However, any such benefits of the workshops would be short-lived if the exercise is not planned and organised properly. Measuring to see if the learning objectives have been met should also not be taken for granted [16]. It would be critical for facilitators to make objective evaluation on students' learning performance and share the evaluation results with students. This would help identify areas for strengthening student performance and for seeking continuous improvement on the design and delivery of the workshop.

Using the facilitators' assessment of the 2002 Industrial Engineering class in the PPC course at UWI, the effect of the workshops was considered positive. Despite variations in the performance among individuals and teams in the PAPLANE-II workshop, the following findings based on facilitators' observations and non-rigorous interviews with students could be made:

1) The workshop positively influenced the nature of the leadership and participatory nature of group-functioning.

2) The workshop worked out well with self-monitoring and cross-auditing process to monitor the performance of students and teams.

3) Teams found that their decision-making process was more defined, consensus-oriented and was not dominated by individuals. They became more satisfied with the team's process.

4) Students found that they were more prepared to give and receive ideas from others, and that there was more active, equal participation. There was less alienation of team members.

5) Students were more satisfied with the team's output, and more committed to the team's outcome. Discussions were generally more relevant and time was utilised more efficiently.

6) Information was shared more readily, and intra-group communication was improved. This facilitates student participation to attain an accelerating learning performance.

7) Students learned to adapt to changes and to strive for the best performance. They were able to identify problems that may not be solved by simple training, while developing their leadership and problem-solving abilities.

8) Students enjoyed the group experience, and found the overall experience more pleasant. The feeling, that they worked well together as a team, also increased over the course of the workshop.

Participants (students) bebefitted from the cross-fertilisation of ideas, experiences and practices that inevitably emerged from members and other teams. The learning process empowers students and brings out a positive team spirit to perform and achieve a shared goal. In addition, the delivery of the workshop also accommodates a wealth of objectives and flexibility of design. Transfer of learning would be increased with action-learning since students are able to take immediate action [4,22].

7. Discussion and Conclusion

Action-learning or experiential learning techniques have been increasingly popular since the 1990s. Business and educational institutions are increasing their use of both in-house and outdoor workshops. There is a need that grows parallel to the popularity of action learning – the need to ensure that activities are effective and have measurable positive outcomes that relate to defined objectives [16]. Built upon the concept of action-learning, action-based teaching makes use of collaborative inquiry process with fellow students. ABT differs from other methodologies (e.g., simulation, case studies or business games). Since ABT is a performance-driven and learner-centred approach around the 'need' to find a solution to a real problem.

With the recent development of IT-oriented and Internet-based teaching, it is anticipated that the ABT approach would motivate students to solve open-ended problems by 'developing skills through doing', and allow them to have a face-to-face contact with their peers, lecturers and tutors. Incorporating ABT into the PPC course can facilitate people participation and teamwork, and help lecturers to instill IE skills and knowledge to students with a balance between theory and practice.

The PAPLANE-II workshop serves as an integral part of the course. The design and delivery of the workshop integrated seamlessly, various ingredients of experiential learning, teamwork, group decision-making processes and other elements that may be missing, into conventional IE courses. This involves carrying out team objectives and embodies the organisational functions from product design to auditing and managerial reporting in a competitive environment.

To be the champion team involves applying these skills to making timely decisions and managing contingencies in such dynamic production-planning and control environments. This is the result of a team effort towards common objectives, where the leaders and individuals assume their responsibilities and perform their tasks with the support from others. The workshop also allows students to experience the cross-functional activities in production operations, and facilitates individual and group learning through applying and integrating knowledge and skills. The self, peer and facilitators' evaluation of student performance at the end of the workshop suggests that the effects measured are enduring and that the workshop is a key ingredient to successful team building in the course. The UWI experience in adopting action-learning shows that ABT is an effective supplement to the conventional classroom teaching and computer-based training in teaching IE courses.

Nevertheless, resource constraints, bias, lack of time and control would always disrupt the workshop in some ways. The robustness of the design and delivery of the workshop needs to be tested. Future research would investigate different methods of measuring the effectiveness of action/experiential learning techniques and the improvements in student-learning performance at UWI and other universities. For instance, the use of performance dimensions and elements would be examined, using the self and peer evaluation exercises, for classes of varied sizes and different engineering courses at UWI. The comparison of findings would help determine the applicability and relevance of ABT to the improvements in student-learning performance. Moreover, the integration of ABT with computer-based training and the evaluation of overall value of ABT are also emerging research areas to be explored.

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