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The Taxonomy for Learning, Teaching and Assessing: Current Practices at Polytechnics in Bangladesh and its Effects in Developing Students' Competences

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Abstract: Polytechnics in Bangladesh endeavour to produce quality graduates for national and international job markets. The quality of graduates depends on several factors. This study examines the implementation process of the polytechnic curriculum with the objectives of determining the current level of practices in learning/teaching material design, in delivering curriculum content, in assessing students and its effect on students' competence development. Data was collected through observation, opinion survey and competence test. Qualitative and quantitative methodologies were used for data interpretation and analysis in this descriptive type of research study. Findings revealed that the learning materials are mainly theory oriented and mostly cover those contents usually common in exams. About half of teachers are aware of the taxonomy for learning, teaching and assessing, but they rarely put importance on it. In the classroom, teachers spend only a little time for delivering content at the level of *apply/analyse*. However, a significant number of tasks performed in labs are practical and occupation relevant and can be classified at higher levels of the taxonomy. In student assessment, the test-items assess mainly theoretical knowledge at the level of *remember*. The effect of these practices is reflected in demonstrating student performance in a competence test. The study concludes with some recommendations.

Keywords: Taxonomy, Competence, Learning, Teaching, Assessment, Technical and Vocational Education and Training, TVET, Diploma in Engineering, Curriculum Implementation, Polytechnics, Bangladesh

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1 Introduction

The intended results at the output and outcome stages of systematic learning-teaching process in technical and vocational education and training (TVET) are workplace-relevant qualification and competences, work-related social competences and general individual characteristics of learners (e.g. Rauner et al., 2007; KMK, 2007; Bader, 2004; Ott, 1998, w.r.t Lempert, 1986). Therefore, TVET curricula objectives are set to provide the trainees/students with the expertise in techniques or technologies (the domain-specific competences) relevant to an occupation, including other constituents of occupational competences (Boreham and Fischer, 2009; Tippelt and Amoros, 2003; Ellström, 1997). The curricula content should be more relevant, practical and useful than general education (e.g. Dare, 2006; Plank, 2001; Finch and Crunkilton, 1999), and the implementation process should enable students to learn/achieve these competences/learning outcomes, and finally they (intended competences/learning outcomes) should be checked through assessment and evaluation systems.

However, the development of students' occupational competences depends not only on a well-designed curriculum but also on many other factors, such as instructional quality, content delivery, student assessment approaches (curriculum implementation) and the quality of learning/teaching materials, among others, (e.g. Geißel, 2008; Fretwell, Lewis and Deij, 2001; Helmke and Weinert, 1997; Biggs, 1995). In the process of student performance assessment, the assessment procedure and performance measuring tools/instruments play an important role in developing students' competences (e.g. Bieg and Mittag, 2009; Nickolaus, 2008; Geißel, 2008; Hopkins, 1998).

It should be mentioned that TVET students become involved in learning with a good level of motivation both because they are stimulated intellectually and because they can readily see how their learning applies to their lives (Stone and Aliaga, 2003). Therefore, the TVET curriculum and its implementation should focus not just on *remembering* or *reproducing* but also on *applying* (*transferring*) or even generating new knowledge to specific situations that demand higher level cognitive process/ability (e.g. Ebel and Frisbie, 2009; Hopkins, 1998).

Some research studies have identified problems in TVET institutions in Bangladesh and barriers to the development of TVET graduates' competence. Kashem et al., (2011) and Oxtoby (1997), for example, state that the current TVET curricula, particularly the Polytechnic curricula of the *Diploma-in-Engineering Programme*, is too theoretical oriented, and a huge mismatch exists between the graduates' competence and the *competences in-use* at the workplace, and therefore, they are unable to earn a considerable level of employers' satisfaction. Some other studies have identified other barriers to quality TVET in Bangladesh, such as inadequate professional preparation of teachers in teaching methods, practical skills and industrial experience; a lack of academic supervision; a lack of teacher and institutional accountability; insufficient and unsuitable textbooks and lab equipment; a lack of government initiative and coordination among different levels of education (primary, secondary, tertiary) and among institutions; a lack of teacher-student communication; improper licensing; insufficient student keys and basic competencies at the entry-level; a lack of self-learning facilities at training institutes (for example, using ICT); a lack of modern teaching aids and inadequate attention to research, among others. (e.g. TVET Reform Project, 2015; Haolader and Paul, 2013; Elbushari and Aktaruzzaman, 2012; Shears, 2011; ADB, 2008; WB, 2007; Khanam and Shamsuddoha, 2003).

Irrespective of the above-mentioned problems/barriers, a body of research studies (e.g. Anderson and Krathwohl, 2001; Hopkins, 1998; Savery and Duffy, 1996; Gronlund, 1993; Bloom, et al., 1956) suggests that while designing and organising learning tasks, learning-teaching materials, instructions in classrooms/labs and the assessment tools for student performance measurement, tasks at different complexity levels of the taxonomy should be checked in terms of educational objectives and other factors, which support developing basic and occupation-relevant competences. Since these factors, along with appropriate learning-teaching models, strategies, and so on, contribute to the development of students' competence and should be practiced during the learning-teaching process if desired outcomes are to be achieved.

However, so far as it is known, only a few (or no) research studies have been done which focused on the learning-teaching materials, instructional design and content delivery methods usually used in polytechnic education in Bangladesh in terms of occupational relevance, knowledge categories and complexity levels of the tasks. Therefore, in this study, the researchers investigate the level of practicing the taxonomy for learning, teaching and assessing, more specifically, in learning/teaching materials, in curriculum content delivery in classrooms and labs, and in student assessment at polytechnics in Bangladesh. Furthermore, to determine the effects of these factors (or practices), we measure the cognitive competence level of graduating (final year) polytechnic students. Finally, we make some recommendations as well.

In the following sub-sections, we describe briefly the taxonomy of educational objectives, polytechnic education, the Diploma-in-Engineering Programme, and the occupational profile of diploma engineers.

1.1 The Taxonomy of Educational Objectives

In the 1950s, following the 1948 Convention of the American Psychological Association, Bloom and his co-workers established a hierarchy of educational objectives, which is generally referred to as Bloom's Taxonomy (Bloom et al., 1956). Other approaches of classification of learning content and outcomes are, for example, the New Taxonomy of Educational Objectives developed by Marzano and Kendall (2007), the Structure of Observed Learning Outcomes (SOLO) taxonomy developed by Biggs and Collis (1982), are gaining attention, too. However, Bloom's Taxonomy is still one of the most widely used ways of organizing learning content and student learning outcomes (levels of expertise) and is considered as a "foundational element" in education (Shane, 1981). Therefore, this study considers the latter one (Bloom's Taxonomy).

Bloom's Taxonomy, which deals with the cognitive domain (knowledge, comprehension and the development of intellectual attitudes and skills), refers to the classification of educational objectives (at different levels – ranging from the simplest behaviour to the most complex) that educators set for learners (learning objectives). A goal of this taxonomy is to motivate teachers/educators to focus on different levels of this taxonomy, creating a more holistic form of education (Bloom, et al., 1956). According to Bloom (1956), there are six levels in the taxonomy, moving through the lowest order processes to the highest: knowledge, comprehension, application, analysis, evaluation and synthesis. Anderson and Krathwohl (2001) revised the original/classic Bloom's Taxonomy to incorporate advances in learning theory and practice since its inception, and offered the following two-dimensional framework to describe learning objectives:

Table 1: Cognitive Process and Knowledge Dimension

		Cognitive Process Dimension →					
		Remember	*Understand*	*Apply*	*Analyze*	*Evaluate*	*Create*
Knowledge Dimension →	Factual	Remember Facts	Understand Facts	Apply Facts	Analyze using Facts, Concepts, Principles and Procedures	Evaluate using Facts, Concept, Principle and Procedures	Create using Facts, Concepts, Principles and Procedures
	Conceptual	Remember Concepts/ Principles	Understand Concepts/ Principle	Apply Concepts/ Principle			
	Pro-cedur-al	Remember Procedures	Understand Procedures	Apply Procedure			
	Meta-cognitive	Remember Metacog. Strategy	Understand Metacog. Strategy	Apply Metacog. Strategy	Analyze using Meta. Strategies	Evaluate using Meta. Strategy	Create using Meta. Strategy
			Knowledge	Skill	Ability		

Notes: Source: Dalton, 2003, Heer, 2012, with reference to Anderson and Krathwohl, 2001.

This two-dimensional framework distinguishes among the types of knowledge being learned (e.g. fact, concept/principle, procedure, m) and the type of cognitive process being employed (remember, understand, apply, analyze, evaluate, or create). In the left-most three columns, there is a strong correlation between the level of cognitive process and the type of knowledge content. For example, learners are often expected to remember facts, understand concepts/principles and apply procedures. However, creating learning objectives in the other cells is also possible, including apply facts and concepts. In each of the relatively more complex cognitive processes (analyze, evaluate and create), multiple types of knowledge content are generally employed. Often, another set of terms (knowledge, skill and ability) are used to characterize these objectives, as shown along the bottom of the framework (Dalton, 2003).

A curriculum, particularly the TVET curriculum, includes content of different levels of learning objectives (Bloom et al., 1956; Anderson and Krathwohl, 2001; Marzano and Kendall, 2007). Therefore, learning/teaching activities and assessment should focus on achieving these learning objectives.

1.2 Polytechnic Education and the Diploma-in-Engineering Programme

The *Diploma-in-Engineering* programme of Bangladesh Technical Education Board (BTEB) is implemented through Polytechnic Institutes or similar TVET Institutions and leads to a diploma level qualification for mid-level technicians/supervisors/managers/diploma engineers. It corresponds to Bangladesh National Technical and Vocational Qualification (NTVQ) Level 6 (NTVQ, 2012; BTEB, 2014) and can be referenced to the Upper Secondary Technical/Vocational Level 3 and Non-Tertiary Level 4 qualification with the provision of direct access to the job market and to the tertiary level of higher education (ISCED, 2011; ISCED, 1997). Students who acquire lower secondary qualification with a minimum of 10 years of schooling (ISCED Level 2) can enrol to this diploma programme. The curriculum of this diploma programme is developed by the BTEB. The duration of this programme is four years and is divided into eight semesters, including one Internship Semester at Industries. Unlike other forms of competency-based TVET curricula or training standards, for example, Germany's learning-area-based framework (Lernfeld) curriculum (KMK, 2008; KMK, 2007), the diploma curriculum in Bangladesh is traditionally organized according to subject. Very recently, (from 2011 to 2014) the curriculum of this programme has been reviewed to address the changing requirements of the job market. The curriculum has about 50 taught courses (subjects), having a total of 162 credits in different subject categories, such as occupational/domain-specific subjects (90 credits, 56%); cross-occupational subjects (19 credit, 11%); mathematics and natural sciences (24 credits, 15%); arts, humanities and social sciences (13 credits, 8%); business competence and environmental studies (10 credits, 6%); and industrial attachment (six credits, 4%). These subjects are delivered in theory and practical/lab classes in a school-based setting with 12 weeks of industrial placement training in the last semester.

At present, 49 public and 385 private polytechnic institutes (including NGO/not-for-profit) offer the four-year *Diploma-in-Engineering* Programme. In 2014, the total actual enrolment in public institute was 22,916 (including 3,899 female; 17.01%) in double shifts (morning and afternoon sessions), and it was 29,742 (including 1,925 females; 6.47%) in private institutes. It should be noted that the actual enrolment drifted slightly downwards from the actual enrolment in the previous year (2013), where the figures were 23,463 (including 3,338 females; 14.22%) and 34,332 (including 2,439 females; 7.10%) in public and private institutions, respectively (source: BTEB official current data, as of 6 December 2014).

1.3 Occupational Profile of Diploma Engineers

The typical fields of activities of a *diploma engineer (in Electronics Technology)* may be, for example, production automation, process automation, network automation, traffic management systems, building security and automation systems, radio and television production, service industries and other electronic systems. Graduates can also be employed in hospitals, infrastructure facilities and industrial plants. Other fields are ICT devices, medical devices, automotive systems, systems components, sensors, actuators, micro systems, EMS (Electronic Manufacturing Services), and measurement and testing technology (Haolader, 2010).

Duties and responsibilities may include producing, putting into operation and maintaining components and devices and integrating, putting into operation, monitoring and maintaining electronic systems and automation solutions. Diploma engineers also provide technical and organizational services, conceive new ideas and install safety, monitoring and surveillance techniques. They install data networks, fire and burglar alarm systems, access control systems, video monitoring systems, and telecommunication installation; they also operate these installations. They develop, install, configure and parameterize software and test IT systems. Moreover, they work independently, take economic and environmental concerns into consideration, and observe the relevant technical regulations and safety rules and coordinate their work with the preceding and following activities. They often work as part of a team [ibid.]. Vocationally organised work is becoming multidimensional, and hence the qualification requirements (the competences) in today's workplace are also multidimensional (e.g. Winther and Achtenhagen, 2009;

Hensge et al., 2008; KMK, 2007; Bader and Müller, 2002; Sloane and Dilger, 2005).

2 Scope and Objectives of the Study

Within the TVET sub-sector of Bangladesh, this empirical study was delimited to polytechnic education, particularly the study focused on the implementation process of the *Diploma-in-Engineering (Electronics Technology)* curriculum (learning-teaching and assessing) and the learning-teaching materials usually used by polytechnic students and teachers in Bangladesh. The aim of study is to improve the effectiveness of learning/teaching in achieving students' learning outcomes. The findings of this study would be used in designing learning materials, planning instructions and developing assessment tools which will contribute to more effective implementation of the diploma level curricula in Bangladesh.

The specific objectives of this research work were to:

- examine how the content of the learning-teaching materials for polytechnic education in Bangladesh is designed in terms of learning objectives;
- determine the level of practicing the educational taxonomy for learning, teaching, and assessing with respect to the curricular objectives, and
- determine how the above mentioned factors influence the development of students' competence by assessing the level of students' cognitive competences that they achieved throughout their study;

3 Methodology

This is a descriptive type of research study which employed both qualitative and quantitative investigations to address the research objectives. *Firstly*, we observed what type (English and/or Bengali medium) of learning-teaching materials are usually used by teachers and students in polytechnic education. Authors' long experience in working with the polytechnic education system helped a lot in this process of data gathering. For examining how the content of learning-teaching materials is designed, the qualitative methodology was used, whereby we studied the mostly used course related to learning-teaching materials (books/handouts, etc.). *Secondly*, for determining the level of awareness and practices of the educational taxonomy during teaching, an observation technique was used, whereby we directly observed teachers teaching in the classroom and labs. To aid the observation, a tool was developed for surveying teachers' opinions on the quality of learning teaching materials and the level of awareness and practices of the educational taxonomy. The questionnaire consisted of *statements* (where the participants expressed their opinions on a 5-point Likert-type scale), *item-selection* and *open type* items. Further data was collected through studying the assessment tools (question papers of semester final exams from the last three to five years) used for polytechnic students' assessment. *Thirdly*, students' cognitive competences were quantitatively measured through a separate self-designed competence test. The competence test consisted of 16 application-oriented tasks covering the core area of the occupation of an electronics technician, such as electronics, micro-controllers, relays/contactors, sensors, information technology, industrial communication, uninterruptible power supply (UPS), electrical motors/drives, machine safety and small controllers/PLCs. The tasks were structured consisting of several test items that demand skills and knowledge at various levels of the cognitive process and knowledge dimensions, which would be required in practicing a student's future occupation. For example, Task 1 was *an electronic control circuit with galvanic isolation mechanism using relays, contactors and a two-input digital NOR-logic module*. The schematic diagram of the circuit was provided. Such types of electronic circuits are often used in electronic controls where the control circuit (low voltage side) must be separated from the main power circuit (relatively high voltage side). Students were asked to *determine the outputs and hence the state (on/off) of the main power circuit for given possible input logic levels at the control circuit*. Task 2 was regarding a motor control circuit using magnetic contactors. Students were asked what the consequence would be due to a wire breakage between two given terminals. Task 3, 4 and 16 were constructed using PLC and sensors with a basic application. Supplementary information, diagrams and so on were provided to assist them in answering the questions related to these tasks. In Task 9, students were asked to *complete a given incomplete circuit diagram that connects the chip MAX232 to a serial port of a microcontroller and to a nine-pin sub-D connector*. For this task, the required datasheet for the chip was supplied. Similarly, the rest of the 16 tasks were relevant to one or more core learning fields, as mentioned above. The complete set of tasks can be supplied when requested. The tasks were didactically simplified. Thus, based on the design, the test items should have measured students' competencies at the cognitive process level of *remember*, *understand*, and *apply* or in terms of the major types (*factual*, *conceptual* and *procedural*) of knowledge, according to Anderson and Krathwohl's (2001) revision of the original Bloom's Taxonomy (Bloom, et al., 1956). Furthermore, during the test design, the authors considered the fact that the knowledge about constituent elements of (upcoming) learning fields is usually the largest contributor to the explanation of the variance of the learning success, or to the predicted performance of one's future development (Knöll, 2007; Nickolaus et al., 2006; Nickolaus et al., 2005). The item-wise validity of the test was examined by experienced teachers and experts in the field of electronic technology. They (experts/teachers) assessed each of the test items on four given criteria and marked them on a 5-point answer scale, from 1 (very low) to 5 (very high). These criteria were: 1) workplace relevancy (application oriented) for the occupation of diploma engineer (electronic technology), 2) whether the test items were within the syllabus (content-related validity), 3) the degree of complexity, and 4) the comprehensibility. Based on the experts'/teachers' opinions, almost all the tasks included in the test were ratified as practical and relevant, where about 75% of the tasks were graded with nearly 4 or above (highly relevant), and only a few tasks were graded with 3.5 on the 5-point scale. According to teachers' opinions, all tasks were within the syllabus. However, a few teachers who validated the test acknowledged that some course contents related to a few number of test items/tasks were taught only about 25% to 50% and were mainly addressed theoretically, not practised in lab classes. In terms of "the degree of complexity", all tasks were rated with points between 2.0 (easy) and 4.0 (complex). The comprehensibility levels of all the tasks were between 3.6 and 4.6 on the 5-point scale, while 1.0 means "very low" and 5.0 means "very high". A pilot test was carried out with a small group of students. On the basis of the pilot test results and experts' opinions, some tasks were redefined, rearranged or explained for better comprehensibility. The time duration of the test was closely observed during the piloting phase and was fixed to a predetermined 50-minute test time. To determine the reliability of the test, the Cronbach coefficient, α (alpha) and the Spearman-Brown coefficient were calculated and found to be 0.858 and 0.890, respectively;

the calculations were made in consideration of all 16 tasks in a group. After classifying the test items into three separate categories (*remember*, *understand* and apply), we calculated the reliability coefficients, as shown in Table 3.1.

Table 3.1: The Results of the Reliability Test

Types of Test	Total	Remember	Understand	Apply
Cronbach coefficient	0.858	0.603	0.677	0.725
Spearman-Brown coefficient	0.890	0.596	0.783	0.659

Convenience sampling was used, whereby 50 teachers from six selected polytechnic institutes participated in this survey/interview, and a total of 150 graduating students from the same six selected polytechnic institutes in Dhaka and nearby cities in Bangladesh took the test. These institutions represent the country in the sense that they are among the biggest and oldest institutions in Bangladesh. The total number of teachers and students of the Department of Electronics Technology and the sample size at each of these institutes are given in Table 3.2.

Table 3.2: The number of teachers and students at the participating polytechnics

Institutes	#Teacher (#Female)		# Student (Female)	
	Total	Sample	Total	Sample
DPI	12 (5)	10 (3)	80 (20)	25 (6)
DMPI	17 (12)	17 (12)	80 (80)	25 (25)
CPI	7 (2)	5 (1)	80 (10)	25 (04)
UPI	5 (1)	5 (1)	40 (10)	25 (3)
AUST	7 (2)	7(2)	40 (7)	25 (2)
IIST	9 (1)	6 (1)	40 (5)	25 (2)
Total	57(23)	50 (20)	360 (132)	150 (42)

Out of the total 50 teachers, 38 (76%) have over five years of teaching experience, and the remaining 12 teachers (24%) have teaching experience between two and five years. Seven teachers have diploma qualification, 24 have a bachelor's degree, and five have a master's degree in a relevant field of technical education or electrical and electronic engineering.

The selection was based on the presence of students at the test time. We administered the test in the presence of a class teacher. At the beginning, students were motivated to take the test by explaining the purpose of it. For example, we mentioned that though this test they would be able to compare their competence level with others in the participating polytechnics, as there would be a common merit list among all the students. Also, they would know how well they are prepared for their future workplace. Furthermore, the presence of a mix of simple and relatively complex tasks helped the students to stay motivated and to maintain their concentration throughout the test. The quantitative data was analysed using SPSS statistics.

4 Findings

4.1 Practicing the Taxonomy in Designing Learning/Teaching Materials

The learning/teaching materials, which are usually used by polytechnic students and teachers, were studied to examine how their content was organised and presented. It was found that a majority of these learning materials (books and modules) for technical (domain specific) subjects focus mostly on facts, definitions, working principles and descriptions of devices, circuits, and so on. The content that can be categorised as higher–level cognitive processes often included synthetic/theoretical tasks and did not simulate real workplace situations. However, some of the Bengali medium textbooks explained the conceptual knowledge nicely. But, in several cases, it was explained using (high level) mathematics, ignoring the conception of didactic reduction methodologies. For example, in a text book written for the "Basic Electronics" course (subject code 6811), ripple factor, efficiency and transformer utilization factor (TUF) (defined as the ration of power delivered to the load and AC rating of the transformer secondary) are calculated using calculus. The recommended reference books for (applied) mathematics are the same books as general higher education. In these math books, it is not clearly explained how the math knowledge can be applied/transferred to solve technical (occupational) tasks/problems relevant to occupational activities in the field of electronics technology. Furthermore, the authors found that a majority of teachers and students mainly use Bengali medium books/lecture notes. These books/lecture notes are often theory oriented, and learning tasks are not didactically designed particularly for mid-level engineering technology education. Different authors of these translated Bengali medium-level books often use differently translated engineering terminologies, which foster confusion among students. It should be mentioned that medium-level English books are available, particularly in government run polytechnics, but they are rarely being used.

4.2 Practicing the Taxonomy in Classrooms/Labs and in Assessment

To determine the level of awareness and practicing the taxonomy of educational/learning objectives (e.g. Bloom's/Bloom's Revised Taxonomy, Biggs and Collis's SOLO, Marzano and Kendall's New Taxonomy of Educational Objectives) by the polytechnic teachers in classrooms/labs, individual teachers were asked for their opinions on a rating scale. Their responses are shown in Table 4.1.

Table 4.1: Teachers responses (out of 50) regarding awareness and use of the Taxonomy

1	2	3	4
never heard of it (Taxonomy for learning, teaching, and assessing)	a little knowledge only, and they don't consider applying it consciously	a good concept, and they apply it in teaching and assessing student performance	an excellent concept and they apply it in teaching and assessing student performance
24 (48%)	24 (48%)	2 (4%)	Nil (0%)

The data shows that about half of the polytechnic teachers have never heard of the taxonomy of educational/learning objectives. Among the other half, almost all teachers who have a years of teaching experience are informed of the Bloom Taxonomy, Bloom's revised version or other taxonomies; however, they admitted that because of the lack of a clear conception of the taxonomy, they seldom consider it in lesson planning consciously and thus in teaching and also in assessing their student performance. Furthermore, they admitted during the interview that they feel reluctant towards using the taxonomy due to the long tradition of not practicing it in teaching and assessing.

In an investigation on how teachers utilize their contact hours during their classroom teaching and assessments of student performance (for the theory part of the course), we found that about 30% of the total allocated contact hours are spent on average for delivering/assessing factual types of knowledge at the *remember/reproduction* level, 60% for delivering/assessing conceptual types of knowledge at the *understand*/r*eorganize* level, and only about 10% of the contact-hours spent for delivering course content at the *apply*/*analyze* (Transfer) level. It should be mentioned that a learning content/task often consists of different types of knowledge at different levels of taxonomy, and we tried to classify each item to a level/category which contributes the most based on our assessment.

Polytechnic students perform practical tasks/lab experiments in labs. For each technical course, there is a list of practical tasks. We found that in this list, a significant number of tasks can be classified at higher levels of the taxonomy and are practical and relevant. However, even in a curriculum/syllabus, these lab experiments/tasks are often not clearly described with their possible practical applications and conditions under which students should demonstrate their performance. It is also observed that teachers are often not well prepared with job/task specification sheets and do not fully utilize the allocated time for lab classes. Moreover, due to many reasons/obligations, students cannot make use of lab facilities of their institutions outside the normal official opening time (usually 8:00 a.m. to 5:00 p.m.) for accomplishing their project work or home tasks, if necessary. Even during the official opening time, in most cases, students' entrance or use of labs/workshops are restricted to only within their scheduled lab class time. Thus, student's willingness to try and test their ability to transfer their learned theoretical knowledge into a new/practical situation is often hindered and not well fostered.

To determine the level of practicing the taxonomy in student performance assessments, we examined the question papers of semester final exams for the previous three to five years. We found that the exam question papers were organized under three groups: Group A – very short objective type questions, Group B – short objective type questions and Group C – essay type questions. Group A was allocated 25% of the total marks and consisted of 10 to 15 very short objective type test-items. These test items were usually selected from the whole course content with the main objective to measure students' ability to remember ("reproduce") factual information. Group B was allocated approx. 25% to 40% of the total marks depending on the length of courses. It included five to 10 short (objective) test items. Items in this group mainly measured students' competence in reproducing factual knowledge at the cognitive process level of *remember* and to a little extent at the conceptual knowledge level of *understand*. Group C was allocated 38% to 50% of the total marks. From this group, students had to answer four/five essay type questions out of five/six items (BTEB, 2014).

The authors found that the test items in Group C measured mainly theoretical knowledge at r*emember* and u*nderstand* levels. A majority of the test items in this group are typical, and ask students to do things such as describe the block diagram, the working process, the architecture, the pin diagram and the functions of some (basic) devices and systems. For example, in assessing students' competences in computer programming language, test items involved writing computer programs to *compute* the real and non-real roots of a quadratic equation; *compute* the factorial of any positive number, *compute* the first 10 Fibonacci numbers, and *arrange* 10 numbers in ascending/descending order. Though these kinds of test items may assess students' knowledge and understanding of a particular programming language, they cannot assess students' capability to transfer this knowledge and understanding in solving workplace relevant tasks, such as programming a microcontroller-based electronic system, which is relevant to the occupation of an electronic technician/diploma engineer. The test items in BTEB final exams over the last three to five years were categorized according to Bloom's Revised Taxonomy (see Table 4.2). The percentage levels of these test items under the category of *remember* (recalling of facts, terms, principles, definitions and descriptions), *understand* and *apply* were 51, 43.9 and 5.1, respectively. This data reflects that the focus of the assessment is on lower levels of cognitive skills.

Table 4.2: Category of test items in exams according to Bloom's Taxonomy

	Remember	Understand	Apply/Analyze
Factual & Conceptual knowledge	48.1%	42.6%	0.8%
Procedural knowledge	2.9%	1.3%	4.3%

It was also found that in assessing some common subjects, the same exam question paper was used. For example, the exam paper of the subject *Programming in C* was used to assess students in courses such as Civil/Construction, Electronics, Mechanical, Survey, Garments Design and Patter Making Technology. The authors understand that although the course content of these common subjects is the same, the learning objectives/outcomes of these types of courses are not exactly the same for different occupations, and therefore, the exam questions should measure learning outcomes that demand cognitive processes at various levels and are relevant to student's future occupation.

4.3 Student Performance in a Competence Test

Polytechnic students' performance was assessed through a self-designed competence test described briefly in Section 3.

In the test, the overall student performance was far below the usual pass level of 40 per cent. Their performances in the taxonomy levels of *remember*, *understand* and *apply* were found as 18.2%, 10.0% and 2.6%, respectively (see Table 4.3). This means that student performance in solving tasks gradually deteriorates as the tasks demand higher cognitive process levels. These results clearly indicate that the practice of using the learning taxonomy with a particular focus at higher levels is inadequate.

Table 4.3: Student performance at different levels of the cognitive process (out of 100)

Cognitive process levels	Marks obtained (in %)	SD	Med	Mod	Min/Max
Apply	2.6	2.9	2.2	0	0/11
Understand	10.0	8.2	8.9	4.4	0/37.8
Remember	18.2	10.1	18.8	21.9	0/51.6

As mentioned earlier, in measuring student performance, we included six classes of polytechnic institutes in Bangladesh. We used the general linear model and univariate variance analysis (ANOVA) to investigate whether there were any differences in the performance among institutions/classes. A profile of the different class averages of student performance is presented in Fig. 1.

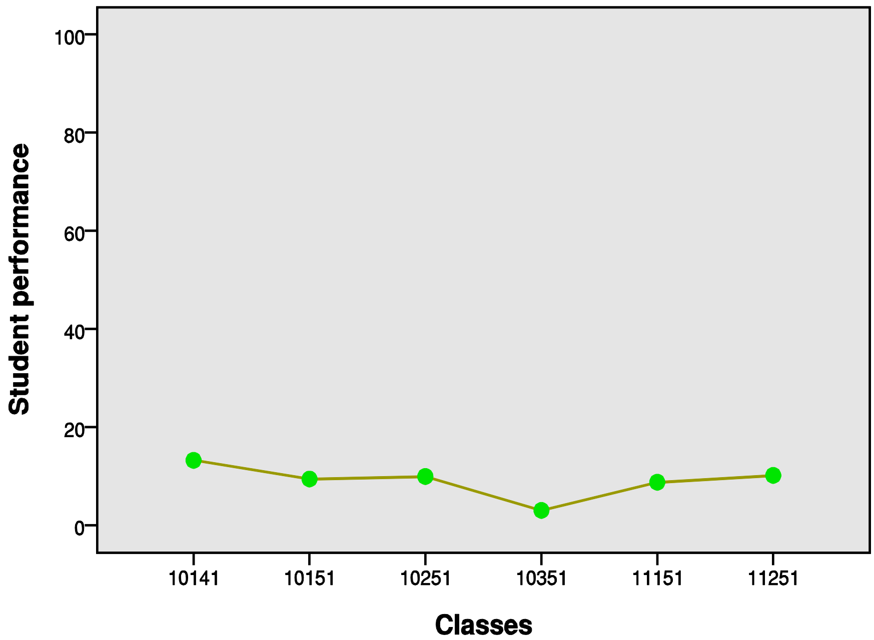

Figure 1: Profile of class means of student performance

Table 4.4: Results of ANOVA test.

df	F	Sig. p	η_p^2
5, 154	15.43	< .001	0.334[a]

a. R Squared = 0.334 (Adjusted R Squared = 0.312).

In the results of the ANOVA test (see Table 4.4), that is, the F value = 14.43, the significance of the F (Sig. p <0.001) and the partial eta squared (η^2_p) show that there are significance differences when the six classes/institutes are compared. Although each polytechnic differs in performance when compared with the others, we further examined these classes/institutes to identify any performance similarities; therefore, we applied Student Newman-Keuls test (also labelled as "post-hoc" analysis). This test result showed that the student performance in these six classes/institutes can be grouped into three sub-sets of classes (see Table 4.5). The lowest performance was shown by a public polytechnic outside Dhaka. A women's polytechnic in Dhaka performed the best among all the participating classes/institutes in the test. The rest showed nearly equal performance in the competence test.

Table 4.5: The class means and the homogeneous sub-sets

Student-Newman-Keuls a,b,c

Class	N	Sub-set of classes		
		1	2	3
10351	19	3,000		
11151	38		8,737	
10151	28		9,429	
10251	37		9,932	
11251	13		10,154	
10141	25			13,220
Sig.		1,000	604	1,000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 15,228.

a. Uses Harmonic Mean Sample Size = 23,201.
b. The group sizes are unequal. The harmonic means of the group sizes are unequal. The Harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = ,05.

It is hard to comment on these overall and individual class performances; however, as mentioned earlier, student performance development depends on many factors, not only on the learning-teaching process or materials, institutional learning environment or individual activities but also on other external factors, such as socio-political-economic conditions, which are not addressed in this study.

5 Conclusions, Discussion and Recommendations

This study mainly focused on learning/teaching materials and the curriculum implementation process (course delivery and assessment) and finally assessed the level of student achievement at the end of the four-year Diploma-in-Engineering study programme/course. The findings of this study are discussed in the following three sections:

The status of learning/teaching materials

It is usual that in determining the learning content of learning/teaching media for technical and vocational levels of education, there is an essential overlapping area between the professional knowledge of university graduates, who require (high profile) professional knowledge, and the professional knowledge of TVET institution graduates (Nickolaus 2008, p. 58, with reference to Grüner 1978, p. 78). However, *technical knowledge* is to be delivered to the technicians/skilled workers in a simplified form, whereas other type of knowledge (for example, DIN rules and regulations and IEC standards) within this common (overlapping) area can be shared by both groups of professionals (ibid.). For a simplification of the knowledge form, didactic reduction methodologies (e.g. the didactic reduction according to Hering, 1998; Grüner, 1978) can be applied (Nickolaus, 2006, p. 59). Furthermore, in designing learning/teaching media, one must know what functions (the media) should be fulfilled (visualization, information, etc.) and what process should be integrated into the curriculum (cognitive structures, methodical procedure, etc.). On this level, we must also know what pre-knowledge and pre-experience learners already have. In short, the media should support learners in achieving the intended learning objectives (LOs). From these perspectives, this research study finds that a major share of the content of the learning materials contain declarative (factual and conceptual) knowledge at the cognitive process levels of *remembering* and *understanding*. Relatively less emphasis is on the content/tasks which are practical and relevant and demand the cognitive process level of *apply* or higher. Although some of the medium-level Bengali textbooks explain conceptual knowledge nicely, in several cases it is explained using (high level) mathematics, ignoring the conception of didactic reduction methodologies. Similarly, a reference book for an applied math course does not include (occupation specific) tasks explaining how mathematical competences can be applied in solving occupation-related technical tasks. Therefore, it can be concluded that many of the Bengali medium-level reference books written for polytechnic education and used as main learning/teaching materials require improved designs in quality, covering well-balanced content from different levels of cognitive processes and types of knowledge.

Practicing the Taxonomy in Classrooms and Labs

About half of the polytechnic teachers who participated in the interview have never heard of the taxonomy of educational/learning objectives. Teachers in this category are either newly recruited (for specific projects) or work on a part-time basis despite a huge number of vacant regular teaching posts. The rest of the teachers are informed of the taxonomy; however, they seldom put importance on student achievement with respect to the desired learning outcomes as stated in the curricula, but rather they address contents which are usually common and frequent in the exams, whereby the focus is how their students can achieve an “A+” (or 80% or above marks) on the final exam. Teachers in this category have a few years or more of teaching experience. They have undergone pedagogical and technical training with a duration ranging from some weeks to months. Some of them have formal qualifications, such as a diploma/bachelor’s degree in Technical Education. Even some of the experienced teachers have post-graduate level qualifications. Statistics on teachers’ background information, such as educational qualification, pedagogical training, and industrial exposure, are not available.

Teachers in classrooms put less emphasis on practical, relevant tasks; rather, they spend a major portion of the class time in delivering theoretical content. In the labs, teachers put more effort into practicing practical and relevant tasks which can be categorised at higher levels of the taxonomy. However, due to management policy and the large class loads per teacher (due to a teacher shortage), they hardly have enough time for preparing lab specification sheets and the like.

Student Performance in a Competence Test

The results of the competence test support the findings stated in Section 4.1 and 4.2., where students' showed relatively better performance in the case of solving tasks in the *remember* category and less performance in the case of tasks at the levels of *understand*, *apply* or higher. However, as mentioned earlier, student performance depends on many other factors. In this study, we focus only on learning/teaching materials and the teaching and assessment practices of teachers, assuming the effect of other factors on the development of student performance as constant. Further, the relative weak performance in the competence test can be explained such that the students were not used to these kinds of tasks; in other words, the tasks were "uncommon" to them. They are more accustomed to school-like tasks, where students learn about individual components separately, not in a workplace-like situation, where components are usually connected and function together in a (complex) system.

This study was limited to polytechnic educations in Bangladesh in the field of electronics technology. Therefore, the findings of this study cannot be generalised. The authors suggest further studies regarding the structure of curricular content, content delivery, and competence assessment following other approaches/models, such as work process knowledge (Boreham and Fischer, 2009) holistic problem solving (Rauner, et al., 2013, p. 165), and subject-based or learning-area-based approaches (KMK, 2007), as well as studies of other institutional and individual context factors.

However, to prepare *diploma engineers* with "*a very broad range of specialised, cognitive and practical skill and comprehensive actual and theoretical knowledge, and ability to creatively solve problems within an occupational activity"* (Moore, 2009; NTVQ, 2012), the authors suggest, among others, that:

- Quality learning/teaching media should be developed with a particular focus on future occupation-relevant content covering relatively higher levels of learning taxonomy. In translated Bengali books, common terminology should be used in all cases; however, students and teachers should be encouraged to use English in teaching/learning, such as using medium-quality English books, in communication and presentation of occupational tasks/assignments.
- In implementing the curriculum, teachers should focus on contents that are at higher levels of the taxonomy. Frequent technical as well as vocational pedagogical training should be arranged for teachers, with a particular focus on the application of taxonomy for teaching, learning and assessing.
- Some of the assessment tasks should be project based with test items constructed from the project(s), covering different levels of taxonomy. Project(s) should be practical and relevant, not synthetic; however, it can be didactically simplified. Solving the test items of the level *apply/analyze* should demand generation of new knowledge ("*knowledge generation*") using factual/conceptual knowledge. The required information could be supplied through a *data sheet*.
- In labs, practical tasks should be designed in such a way that they require the use of handbooks/data sheets. Thus, students will become familiar and accustomed to using technical data in solving higher level tasks. These practices will enhance students' skills in designing, developing, installing and configuring new devices/systems.

- Teachers should establish linkage with their courses taught in relevant industries in fields of their students' future occupation and frequently gather practical skills requirements of the workplaces in the real world.

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