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Updating polytechnic teachers' knowledge and skills through teacher design teams in Ghana

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While teachers and administrators in polytechnics in Ghana have categorically expressed the growing need for the former's knowledge and skills to be updated in the era of polytechnic transformation, little attention has been paid to the subject. This study reports a professional development intervention organised for 16 engineering teachers divided among three teacher design teams (TDT) who planned and undertook industrial attachments to update their knowledge and skills in their subject areas. With relevant knowledge acquired, they updated their courses and subsequently conducted teaching tryouts. Data collected during the study through interviews, questionnaires and a logbook sought teachers' learning experiences in TDTs. The results indicated teachers' acquisition of relevant knowledge and skills during the TDT activities. Furthermore, TDT enabled active learning, collaboration as well as dialogue on subject matter among teachers and was a useful means for the professional development process.

Keywords: teachers; professional development; teacher design teams; knowledge and skills

Introduction

The era when Technical and Vocational Education and Training (TVET) teachers' knowledge and skills acquisition ended with their apprenticeship during their training is fast fading due to permanent change in vocational jobs driven by developments in society and the economy (Harteis 2009). While TVET sectors consider the necessity of workers' lifelong learning, less emphasis is given to the effects of this change for teachers in the TVET field. In an ever-changing industrial environment worldwide, the update of knowledge and skills is a necessary professional development strategy for TVET teachers to ensure that they are equipped with the necessary skills and capabilities for teaching (Choy and Haukka 2009). There are 440 TVET providers in Ghana, among which 188 are public and 252 are private. The types of TVET providers or institutions are varied according to the trade/subject for learning, qualification level and juridical agencies. Among them are the 10 polytechnics in Ghana that provide TVET education at the tertiary level leading to the

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award of Higher National Diploma (HND) and Bachelor of Technology degrees. The aims and objectives of the polytechnics as tertiary institutions are to:

(1) provide tertiary education through full-time courses in the fields of manufacturing, commerce, science, technology, applied social sciences, applied arts and such other areas as may be determined by the authority for the time being responsible for higher education;
(2) encourage study in technical subjects at tertiary level; and
(3) provide opportunity for development, research and publication of research findings.

From the aims and objectives outlined above, the central focus of polytechnic education is to provide programmes that are career-oriented and practical in content. Among the key objectives of upgrading the polytechnics to tertiary institutions in 2007 were to improve the quality of teaching, to increase and improve output particularly in technical and vocational level training and to increase access to tertiary-level education. In spite of this, polytechnic education in Ghana has suffered major setbacks which could be linked to factors such as weak linkages with industry in terms of curriculum development that have further led to a mismatch of supply and demand skills (Owusu-Agyeman and Van den Oosterkamp 2009). The government has constituted the Council for Technical and Vocational Education and Training to coordinate and oversee all aspects of TVET in the country. However the impact of their formation is yet to be felt (Owusu-Agyeman and Van den Oosterkamp 2009). The Ministry of Education, Youth and Sports (2003) reported that in 2002 the proportion of teaching staff and students of technical and vocational institutes on industrial attachment stood at 18%. In recognition of this, a TVET strategy document of the Ministers of Education of the African Union (2007) has suggested that employers provide opportunities for industrial attachment for trainees and for TVET teachers to regularly update their work experience. The Ministers of Education of the African Union acknowledge that the quality of TVET is dependent on the competence of the teacher, which is partly measured by being abreast with new technologies in the workplace.

The problem researched in this study is related to the complex changes that polytechnics are undergoing in Ghana. Due to changes in government financing structures and the upgrade of polytechnics into tertiary institutions, polytechnics are starting to be managed much more like semi-autonomous organisations. Managers of polytechnics are being required to look for new ways of ensuring that teachers are effectively facilitated in their learning in order to cope with the changes as well as to innovate. Professional development of teachers has been one major area of concern in polytechnic education in Ghana (Nsiah-Gyabaah 2005, Gervedink Nijhuis *et al*. 2009). The upgrade of polytechnics into tertiary institutions has called for the maintenance of competent teachers (National Council on Tertiary Education 2001). One key area of concern for professional development as expressed by polytechnic teachers and management in Ghana is for the former to update their knowledge and skills in their subject areas through embarking on industrial attachment (Bakah *et al*. in press). As technology is fast advancing, polytechnic teachers see the need to pursue relevant knowledge to improve on their professional competence and be able to update their courses (Bakah *et al*. in press). Acquisition of knowledge and skills in TVET does not only concern the learners but also the teachers,

who ought to develop their competence over time as circumstances change to better guide the learning process (Craig 2003, Harteis 2009). Thus, successful professional development arrangements are necessary for polytechnic teachers to enrich their knowledge and skills, improve their practical or professional qualifications and be abreast with permanent change driven by developments in society and the economy.

One major means by which knowledge and skills can be acquired by teachers in TVET education is through industrial attachment. Industrial attachment usually refers to the formal placement of trainees in the workplace to facilitate the achievement of specific learning outcomes that would potentially lead to their employability on completion of a training programme (Choy and Haukka 2009). Industrial attachments typically involve training providers and industries (through employers) forming partnerships to offer situated learning opportunities in the workplace so that TVET students and teachers have access to authentic experiences that only the workplace can offer (Choy and Haukka 2009). In the light of the foregoing, industrial attachment is worthy of consideration for TVET teachers. The term 'industrial attachment' for teachers is commonly used in Asian and African TVET systems to describe arrangements allowing them to replenish and update their skills. In other countries, it may be called on-the-job learning for teachers and trainers (e.g. Finland), return or back-to-industry programmes (e.g. Australia) or industry placements or secondments (e.g. the United Kingdom).

Industrial attachment is seen as an effective professional development activity for TVET teachers to maintain the currency of their vocational knowledge and expertise, including their knowledge of technologies and practices commonly used in contemporary workplaces (Loveder 2005). Cort *et al*. identified up-to-date vocational skills and knowledge as one of the competencies needed by TVET practitioners who then incorporate 'what they learn into their own teaching programmes to ensure trainees leave the TVET system with immediately useful skills' (2004, p. 22). Cort *et al*. contend that practical training periods in companies allow teachers to update their skills and knowledge in the subject areas they teach, while encouraging them to experiment with new teaching methods and materials, 'giving them a realistic and holistic impression of the professions, and bringing elements of realism into their teaching' (2004, pp. 38–39). This study explores the impact of a professional development arrangement, in which industrial attachment is embedded, on polytechnic teachers' updating of their knowledge and skills. This is aimed at equipping polytechnic teachers with contemporary developments in the industrial sector for classroom practice. The professional development arrangement makes use of the concept of teacher design teams (TDTs), which will be elaborated on in the next section.

Teacher design teams

Concepts and approaches

According to Handelzalts (2009) a TDT is a group of at least two teachers, from the same or related subjects, working together on a regular basis, with the goal to re-design and enact (a part of) their common curriculum. The TDT concept provides teachers with a creative space to reconsider the teaching of their subject, the intellectual stimulus of working together and the challenge to move their thinking forward (Simmie 2007). TDT is one means by which teachers can collectively

participate in curriculum design, fulfil their learning, social and intellectual needs and are effective in bringing about teacher professional development (Ball and Cohen 1996, Deketelaere and Kelchtermans 1996, Parchmann *et al*. 2006, Mishra *et al*. 2007, Penuel *et al*. 2007, Westbroek *et al*. forthcoming) and curriculum innovation (Mishra *et al*. 2007). Experienced teachers have varying personal and professional needs to develop their creativity, to share their experience, to leave the isolation of their classroom (Simmie 2007) and, according to Jarvis *et al*. (2003), to continue the intellectual challenge of the subject that may have attracted them to teaching in the first instance. Groups of teachers meeting to share and work together provide an opportunity to extend their professional boundaries (Carlgren 1999). Professional activity embeds individuals' learning in the social context of the workplace and gives access to a community of practice (Wenger 2003) and further offers individuals the opportunity of expanding a repertoire of experiences (Billett 2006).

The more teachers are dependent on each other through collaboration, the more potential the interaction has for learning (Handelzalts 2009). Evidence from a wide range of studies of schools suggests that those schools that make extensive use of teacher collaboration are particularly successful in promoting teacher learning (Putnam and Borko 2000, McCotter 2001, Erickson *et al*. 2005). Collaboration in networks can create opportunities for reflection on learning processes and new teaching experiences (Clement and Vanderberghe 2000, Borko 2004, Lumpe 2007, Handelzalts 2009). Collaborative learning adheres to a holistic perspective on teacher professional development (Bell and Gilbert 1996). Teachers' being in a team that collaboratively articulates and recognises a problem in daily educational practice enhances their motivation to redesign that daily practice. Teachers who get help from colleagues who are more expert than they are may also gain important new information from those interactions that extends what they learn from formal professional development experiences (Ball and Cohen 1996). Having multiple participants in professional development from a single school helps to build trust and support relationships (Penuel *et al*. 2009). Furthermore, teachers often report that participating as a group in professional development can give focus to collegial interactions and motivate working through problems of practice together (Little 1993).

Exemplars of the TDT concept and approach can be found in the research of Nieveen *et al.* (2005), where they used TDTs as part of the PIVOT programme: a school-based curriculum innovation to integrate curriculum development with teacher development. The project sought to identify ways to generate more ownership and commitment and to create mechanisms for schools and teachers to come to the forefront of curriculum improvement. Parchmann *et al*. (2006) studied teams of science education researchers and teachers who jointly designed curriculum to support teachers in changing their teaching towards a more context-based and student-oriented teaching. Millar *et al*. (2006) worked with TDTs composed of both teachers and researchers (in a school–university partnership) to develop research-based classroom materials for the teaching of physics and biology. These classroom materials were then transferred to other classrooms with good transferability rates and increased student motivation was recorded. Simmie (2007) conducted a study where biology associates worked with 100 biology teachers in TDTs and together they produced 18 innovative classroom resources, which have now been made available for the teaching of biology in Ireland. His study considered the merits of the TDT approach as a means to contribute to curriculum implementation and continuing

professional development. This study sets forth to maximise the worthwhile opportunities that TDT offers for the updating of polytechnic teachers' knowledge and skills as it addresses the question: what is the impact of teacher design teams, as a professional development arrangement, on teachers' knowledge and skills? In this study we operationally define polytechnic teachers' knowledge and skills as subject-matter-based technical knowledge and skills, curriculum design knowledge and skills and collaboration skills.

The following sub-research questions informed the study:

(1) What knowledge and skills do teachers acquire by participating in a teacher design team?
(2) What is the effect of teachers' learning in a teacher design team on their classroom practices?
(3) What are teachers' perceptions of teacher design teams as a professional development arrangement?

Professional development arrangement

The 12-week programme was composed of six main activities and was conducted through three TDTs, namely Automobile (ATDT), Production (PTDT) and Electrical (ETDT). The activities included an introductory workshop, meetings, industrial visits, course update, teaching tryouts and a dissemination workshop. The introductory workshop, which was held in the first week, oriented teachers on the concept of TDTs. Plenary sessions were held on the issue of industrial attachment for teachers

Table 1. Overview of courses chosen and areas updated by TDTs.

TDT	Course	Class	Areas updated
PTDT	Workshop Processes and Practice 2	HND 1	To select a suitable material for making a mould intended for sand casting, to produce a mould for a given simple engineering component, to produce a casting from the mould
	Installation and Maintenance (Pumps)	HND 2	Procedure for the installation of pumps, process schedules for pumps, maintenance of pumps, trouble-shooting and repairs of faults on pumps
ATDT	Workshop Process and Practice 2	HND 1	The identification and use of instruments to implement quality control checks on modern vehicles
	Vehicle Engineering Science and Laboratory Work 1	HND 2	The use of high-speed engine test indicators and hydraulic dynamometers for various engine tests, such as indicated power, break power, mean effective pressure, specific fuel consumption, heat balance test and thermal efficiency
ETDT	Electrical Machines 1	HND 1	Designing and rewinding single-phase transformers
	Electrical Machines 3	HND 2	Designing and rewinding single-phase induction motors

Note: Higher National Diploma (HND) is below bachelor level.

and its potential for teacher learning and course update. The workshop opened up the opportunity to secure teachers' acceptance of the need to update their knowledge and skills. The first author as researcher was the main facilitator at the workshop, which comprised presentations and discussions.

Meetings of three TDTs commenced in the second week and continued through the third week for teachers to engage in identifying parts of the courses to be updated and a plan of action for the update of knowledge and skills in those areas identified. Each TDT chose two ongoing HND core courses (for years one and two). Teachers collectively examined the contents of the course syllabus and identified topics for update and improvement in terms of classroom practices. Accompanying the decision on the areas for update was the consideration of the feasibility of fulfilling acquisition of the needed information within a day's visit to industry. The courses chosen and areas updated by each TDT are in Table 1. TDTs worked out an action plan to visit industry for more information to support the update of the courses. They then decided on industries to visit and embarked on industrial attachment during the fourth, fifth and sixth weeks. Each TDT industrial visit, which lasted a day, took teachers more than 200 kilometres away from their polytechnic. The ATDT visited Japan Motors Company Limited and Toyota Ghana Company Limited at Accra, while the PTDT visited Gratis Foundation in Tema and Kpeve Water Pumping Station at Kpeve. Electricity Company of Ghana in Tema was the industrial location visited by the ETDT.

After the industrial visit, from the sixth to eighth weeks, series of meetings were held by the TDTs to review industrial attachment and teachers' industry reports. Based on the knowledge and information acquired, courses were updated. During the ninth and 10th weeks, teachers conducted teaching tryouts of the parts of the updated courses that they collaboratively designed in their TDTs, which were subsequently evaluated by the students who took the course. All of the TDT members witnessed the teaching tryout in their respective areas and subsequently evaluated it during the 11th week. Participating teachers disseminated the activities of the TDTs in a seminar in the 12th week, which was open to all teachers in the polytechnic and members of the polytechnic administration. The aim of the seminar was to propagate, reflect on and share experiences of the work of the TDTs and to progress the professional dialogue with regard to the future of TDTs in the polytechnic. In all, six meetings were held per each TDT. The first author as researcher acted mainly as a facilitator and participant observer at all the phases of the intervention.

Methods

Design of the study

This study was designed to explore the potential of TDTs for teachers' knowledge and skills update as the teachers embark on industrial attachment and subsequently update their courses by collaboratively re-designing curricular materials and teaching methods. This research employed mixed methods of data collection in a case study. A multicase study embedded design (Yin 1993) was applied with three cases, the TDTs and teachers and students, as units of analysis. The study investigated teachers' experiences regarding their participation in TDT, teachers' perception of what they have learned from TDT as well as changes in classroom practice that have occurred as a result of participation in TDT: industrial attachments, course update and teaching tryouts. Students' experiences with teaching tryouts were also explored.

Participants

Teachers

Overall, 16 teachers (all males) from the faculty of engineering at Ho Polytechnic took part in the study based on their availability as full-time teachers and upon recommendation by their heads of department. The teachers were grouped into the Automobile, Production and Electrical teams. Background characteristics of the teachers are provided in Table 2. Ho Polytechnic is one of four polytechnics in Ghana where a needs analysis study was conducted to find out the professional development needs of teachers (Bakah *et al*. in press). Ho Polytechnic was purposefully selected among the four polytechnics since it is situated in a low-industrialised region of Ghana and is geographically isolated from industrialised locations.

Students

A total of 478 HND Engineering students (average age 24 years) were involved in the study, of which 212 experienced the post-industry teaching tryouts conducted by the teachers and subsequently evaluated the subject taught. The remaining 266 evaluated the same subject as it was taught prior to the commencement of TDT activities.

Instruments

Teachers' interviews

There were six categories of semi-structured interview data collected from each teacher to find out their experiences during the following teacher design team activities: workshops, industry visits, course update, teaching tryouts, perceptions of

Table 2. Background characteristics of teachers.

TDT	Teacher pseudonym	Age	Highest academic qualification	Years of teaching at polytechnic	Number of HND students
ATDT (n = 5)	Kelvin	53	Master's	16	Automobile Engineering: year one, 55; year two, 65
	Martin	52	Master's	27	
	Felix	42	Master's	7	
	Norbert	64	HND	11	
	Justice	29	HND	4	
PTDT (n = 6)	William	51	Master's	20	Production Engineering: year one, 57; year two, 31
	Patrick	45	Master's	15	
	Alfonse	29	Bachelor's	2	
	Henry	25	HND	2	
	John	55	HND	27	
	Donald	33	HND	6	
ETDT (n = 5)	Larry	50	Master's	13	Electrical Engineering: year one, 142; year two, 128
	Oliver	46	Bachelor's	16	
	Bill	33	Bachelor's	6	
	Roland	28	HND	2	
	Victor	30	HND	2	

Note: Higher National Diploma (HND) is below bachelor level.

TDTs and teacher learning in TDTs. On average, each interview lasted 30 minutes and was audio-taped.

Teachers' questionnaire

Teachers also responded to close-ended five-point Likert-scale questionnaire items (1 = 'strongly disagree' to 5 = 'strongly agree'). Related to teachers' perception of industries visited, two constructs were distinguished; *acquisition of knowledge and skills* (six items) ($\alpha = 0.72$) and *usefulness of knowledge and skills* (eight items) ($\alpha = 0.71$). Teachers also provided responses on their *perception* (12 items) ($\alpha = 0.70$, $\alpha = 0.84$) of TDTs before and after the professional development programme. According to Morgan *et al*. (2004), the alpha values reported here (above 0.70) are reasonable for internal consistency.

Students' questionnaire

Questionnaires were administered to students after the teaching tryout of updated courses. The questionnaires consisted of 19 items on students' perceptions and experiences with the courses taught. Possible answers to all items were on a five-point Likert-scale (1 = 'strongly disagree' to 5 = 'strongly agree'). The questionnaire was administered immediately after the teaching tryouts. After running factor analysis using SPSS, two constructs obtained were *presentation* ($\alpha = 0.89$) and *clarity* ($\alpha = 0.83$) for student responses. *Presentation* in this study refers to the practice of showing and explaining content of the topic to the students, and *clarity* denotes the practice of making content of the topic clear for students' comprehension of the concepts.

Researcher's logbook

A logbook was kept by the first author in order to document the process of teachers working in the TDTs.

Data analysis

Teachers' questionnaires

Teachers' questionnaire responses were analysed using SPSS to compute the means and standard deviations (SDs). Analysis of comparison of teachers' perceptions of TDTs before and after the professional development programme employed the Wilcoxon non-parametric test (Corder and Foreman 2009) on the assumption that the population cannot be assumed to be normally distributed. Effect size was calculated using Cohen's d (Cohen 1988). Cohen (1988) provided tentative benchmarks for the interpretation of effect sizes: $d = 0.2$, a small effect size; $d = 0.5$, a medium effect size; and $d = 0.8$, a large effect size.

Students' questionnaires

Means and SDs were calculated for students' responses and an independent-sample t-test was computed to find out whether significant differences existed regarding the

experiences of participants and non-participants in the teaching tryout in terms of the sub-scales *presentation* and *clarity.* Cohen's *d* (Cohen 1988) was calculated to find out the extent of the differences. A one-way analysis of variance test was conducted to evaluate the extent to which differences exist between the participants' (Automobile, Production and Electrical HND students) perceptions of the lesson they had in terms of *presentation* and *clarity.*

Teachers' interviews and logbook

All interviews were transcribed and coded using codes generated from the study. The coding schemes (Bogdan and Biklen 1992, Miles and Huberman 1994) were labelled: *industrial attachment evaluation*, *course update evaluation*, *teaching tryout appraisal*, *perceptions of TDTs* and *teacher learning in TDTs.* Atlas-ti software version 5.5 was used for the coding of all the interview data. Intercoder reliability (Tinsley and Weiss 2000, Lombard *et al*. 2002, Neuendorf 2002) was calculated using a random sample of eight interviews from 16 teachers. There were two coders including the first author of this article. The intercoder reliability using Cohen's kappa (κ) was 0.93. Information recorded in the logbook was analysed qualitatively using a data reduction technique. Major themes were identified and clustered (Miles and Huberman 1994).

Results

Teachers' knowledge and skills acquisition in teacher design teams

At industries – subject-matter-based technical knowledge and skills

Teachers' (n = 16) evaluation of the industrial attachment revealed that all the teams found the visit relevant. The overall means for acquisition of knowledge and skills (mean = 4.48, SD = 0.32) and for usefulness of knowledge and skills acquired (mean = 4.60, SD = 0.35) were very high.

Teachers' interviews further revealed how they found the industrial attachment very relevant in terms of knowledge and skills acquired and how useful it was for their professional development and classroom practices. Across all the TDTs, every member was emphatic about how significant it was for them to visit industry, as Donald (PTDT) said: '. . . I thought I knew so many things on pumps until I got to Kpeve Pumping Station . . .'. The PTDT indicated their exposure to innovative processes of production, and this was confirmed by William (PTDT): '. . .we were exposed to new processes of casting and varieties of sand . . . it was a very good exercise we went through'. The ETDT were pleased with their skill acquisition, as Roland (ETDT) informed that: 'I acquired new skills in rewinding single phase induction motors and detecting faults. . .'. The ATDT were content with information acquired: 'We were introduced to new models of vehicles and how to conduct quality control checks on them . . .; this is rich information for me and my course' (Kelvin, ATDT). In spite of the wide range of positive responses re-echoing the success of the industrial attachment, all except two teachers from the ETDT and ATDT as well as three teachers from PTDT stated that too limited a time was spent at the industry. Nonetheless, all of them admitted that the targets for the visits were achieved except for extra industrial operations that were of interest to them. Teachers showed keen interest in the industrial visit, took down notes and asked resource

persons many questions. Furthermore, they were eager to try their hands on equipment whenever they were given the opportunity.

During collaborative design – curriculum design knowledge and skills

During the course update, each TDT unanimously chose two ongoing HND core courses (see Table 1) and collectively re-examined the contents for areas to update. They worked out an action plan to visit industry, for additional information on contemporary industrial operations regarding the areas targeted for update, which they successfully accomplished. After regularly meeting for discussions and decision-making, the courses were finally updated in terms of content and pedagogy. In all, teachers expressed the view that their course update was a meaningful exercise. To them the TDT allowed for a participatory approach in updating courses and gave grounds for extensive work in a short period. Teachers admitted acquiring some skills that were critical to curriculum design in the form of content selection and analysis. Teachers also acquired the skill of analysing goals and identifying objectives for the courses they selected. However, the process was not exactly the same for all the TDTs due to some internal team arrangements to enrich their decisions. The ATDT invited the Industrial Liaison Officer (liaises with industries on students' industrial attachment placements and feedback) of the polytechnic to be present to give advice on which industries could best be visited based on the areas to be updated. The ATDT found his contributions to the choice of industrial location useful. At some of the design sessions of the PTDT, the Chairman of the Faculty of Engineering Board (a board that among other things oversee and approve faculty curriculum design issues), who is a production engineering expert, was invited for his contributions on the identified need areas in the courses. The PTDT found him a great resource in their deliberations. Unlike the ATDT and PTDT, the ETDT did not involve any specialist in their course update meetings but rather through two meetings (one for HND year one and another for HND year two) students' views were solicited on the need areas identified for further information to augment ideas for the course update.

The majority of the teachers observed that the course update resulted in the interchange between people's different ideas, making it a mutually productive and beneficial process: '... it helped in the integration and cross-fertilisation of ideas' (Felix, ATDT). Most of the teachers in each team admitted how the exercise made them more aware of the delicate balance between what they think they know and what ought to be taught. Every single teacher felt the sense of ownership for the updated courses, as for instance Justice (ATDT) indicated that:

> ... in fact this is a decentralised way of handling curriculum design especially as long as skill development and practicals are concerned. This is what we need and we want to do. This is in a way encouraging grass root design of curriculum which is very supportive.

It was observed that teachers exhibited clear understanding of the process of updating their courses and employed their subject matter and pedagogical knowhow in the discussion process. Oliver (ETDT) simply said that, 'I am proud of the teamwork to build a relevant syllabus step by step'. Despite the show of common interest, it was observed that one teacher in the PTDT and two in the ATDT did not

open up initially in team discussions about the courses but, upon examining other colleagues' frankness, they began to contribute and be actively involved in the group activity. Across all the TDTs, it was obvious that arriving at a consensus in the selection of two core courses for update was difficult due to varying individual priorities but this challenge was surmounted by unanimous decisions at the end. Justice (ATDT) confirmed this, saying: '... as in every consensus process, we emerged with different opinions, priorities and interest levels ... but we reached a decision afterwards'.

Teacher collaboration – collaborative skills

Teachers pointed out that their involvement in TDT has had considerable impact on their learning. They pointed out that it gave them the opportunity to share knowledge and ideas with colleagues. Donald (PTDT) informed that: '... in TDT I conferred with colleagues, discussed issues openly and learnt'. Most teachers indicated that in TDTs they had the opportunity to reflect deeply on their courses in order to improve them. John (PTDT) said: '... we have a saying that two heads are better than one ... working in a team has improved my knowledge and what to teach'. They learned from colleagues who were experienced, learned to work harmoniously in teams and acquired team-working skills. As a result of working in the TDT, teachers learned to tolerate diverse ideas from colleagues, cope with temperament, compromise and come to consensus on issues. They maintained that the TDT created and sustained dialogue in the academic corridor. According to Oliver (ETDT): '... working as a team, gave me the opportunity to share ideas, come out boldly ... and was motivated to learn'. It was worthwhile to note that the teachers found it interesting to learn together at the industry despite their varied qualifications, age and experiences. Kelvin (ATDT) mentioned that, '... no one is paragon of knowledge. It was a nice opportunity to improve my knowledge among colleagues in TDT'. To them, taking time off duty to travel several kilometres from their polytechnic into an industrial environment was invigorating, refreshing and exciting. They admitted that being in TDT sustained in them the zeal to achieve team targets as they planned for and visited industry and got exposed to new equipment and technologies. Teachers learned by designing, as Alphonse (PTDT) states: 'I had new ideas from colleagues as we examined the syllabuses'. Bill (ETDT) submits that, 'Preventing a static syllabus by delving into it and incorporating current changes from industry gave a boost to our knowledge and the teaching process'. Martin (ATDT) acknowledged that, 'Once I want the students to learn certain things; I must have broad knowledge in that direction. We had this chance to assess ourselves alongside the curriculum'.

Effect on teachers' classroom practices

Teaching tryouts

Teaching tryouts by the ETDT involved rewinding single-phase transformers and single-phase induction motors. They indicated that their department acquired the transformers and induction motors some months earlier but teachers did not have any training on their usage until their visit to industry. In effect, ETDT teachers were of the opinion that students experienced real practical work on the transformer and saw for themselves how the windings are done. To them, new ideas from

industry benefited the course except for unexpected power failure during teaching, which happened twice lasting eight minutes and six minutes, respectively. Another challenge encountered by the ETDT was the large class size. During the teaching tryout by the PTDT, teachers made use of video recordings of the procedure for the installation and maintenance of pumps (recorded at industry) to teach the topic. Teachers informed that at first the topic was taught without students having any pictorial conception since such heavy duty machines cannot be procured by the polytechnic; however, the video helped in communicating a lot of information on varieties of pumps to the students, thus expanding their knowledge. According to them, students found the class really interesting since they had a clear pictorial view of the installation, maintenance and operation of pumps in *PowerPoint* slides and videos. Students' responses to questions and contributions were very encouraging and showed their articulation. The identification and use of instruments to implement quality control checks on modern vehicles formed the core of ATDT teaching tryouts. The ATDT teachers also stated that teaching what was existent in industry was interesting since students watched a detailed video recording on the conduct of quality control checks on modern vehicles instead of the usual outmoded automobile engines in the workshops. They indicated that students showed very keen interest in the lesson.

Students' experiences

There were questionnaire responses of students who were participants (n = 212) in the teaching tryout and students who were non-participants (n = 266). The overall means of aspects of the lesson reported by all the Automobile, Production and Electrical students who participated in the lessons were higher (*presentation*, mean = 3.88, SD = 0.66; and *clarity*, mean = 3.37, SD = 0.63) than for students who did not participate (*presentation*, mean = 3.35, SD = 0.87; and *clarity*, mean = 2.75, SD = 0.79). There was significant difference (p = 0.0001) in terms of both subscales *presentation* and *clarity* between participants and non-participants with large effect sizes of 0.70 and 0.86, respectively.

A one-way analysis of variance test was conducted to evaluate the extent to which differences exist between the participant perceptions for the course they took. It was revealed that no significant difference (F = 2.41, p = 0.092) was found across lessons for Automobile, Production and Electrical student groups in terms of the subscale *presentation*. Concerning the subscale *clarity*, a significant difference (F = 6.91, p = 0.001) existed across lessons. Using the Tukey HSD (Honestly Significant Difference) procedure, multiple comparisons between the three programmes were made to evaluate the pairwise differences among the means for the subscale *clarity*. With respect to the lesson for Production and Automobile students, pairwise significant differences ($p < 0.05$) did not exist in terms of *clarity* (difference in means = 0.08, p = 0.777). However, pairwise significant differences existed among Production and Electrical students' lessons (difference in means = 0.35, p = 0.002) and Automobile and Electrical students' lessons (difference in means = 0.27, p = 0.025) regarding *clarity*. The relatively low means in terms of *clarity* for Electrical students may be attributed to challenges during the teaching tryout, explained by the teachers as very large class size for a relatively small laboratory and the persistent power failure during the lesson where the transformer (which depends on electricity for operation) was being used.

Teachers' perceptions of teacher design teams as a professional development arrangement

Survey data from teachers (n = 16) showed their perceptions of TDTs before and after engaging in the activities. Overall results indicated that a significant difference (p = 0.0001) existed between teachers' perceptions before (mean = 2.50, SD = 0.37) and after (mean = 4.22, SD = 0.37) the professional development activities. Extremely large effect sizes ranging from 1.20 to 3.90 were recorded for all the items.

Teachers articulated their experiences with working in a TDT and were unanimous that some specific elements of TDTs had considerable impact on them. They discovered that working in TDTs was interesting. Specifically teachers liked collaborations, discussions and teamwork in TDTs. According to most of them, teamwork allowed for variety of views to enrich decisions. Teachers agreed that being in a TDT boosted their confidence in the courses they teach as they managed to update them with relevant information from industry. They admitted that it was difficult for an individual to gain attention at the industry, thus with the TDT industries opened up and invested time. They were also of the view that workload and bureaucracy uninspired individual moves to visit industry, however: '... in TDTs we have collectively planned and visited industry... to me, it is a great awakening' (Roland, ETDT). It was interesting to know that, being in a team, colleagues benefited from responses to each other's questions by industry resource persons. Teachers discovered that collaboration and TDT were indistinguishable; enabling crossbreeding of ideas, interacting, sharing information and brainstorming on issues. Norbert (ATDT) stated: '...actually TDTs brought us together, it has taken us a step higher in our career and enhanced unity of purpose'. Larry (ETDT) said: '... TDT fostered good relationships among staff'. With the actual designing of the courses, teachers found it practical and of use in TDTs, as Justice (ATDT) said: 'As we probed the syllabus in TDTs, it shaped my paradigm on the practical training of my students; it was interesting to hear colleagues' contributions on it'. William (PTDT) was of the view that, 'In the design process was the painstaking effort by numerous brains to improve our system of teaching. So TDT is useful'. Victor (ETDT) indicated that, 'Pooling ideas for a holistic course was rewarding, some teaching challenges were highlighted and we factored in students' concerns about the course'.

Challenges of working in a design team

In spite of the numerous positive remarks from the teachers on their TDT experiences, they encountered certain challenges, some of which are generally inherent in teamwork while some concern TDTs in this study. The ETDT had the most challenges since the only five teachers at post all joined the TDT. In Table 3, we present the TDT challenges in this study.

Suggestions

At the seminar to disseminate the TDT activities, teachers made various suggestions. They suggested that TDT activities should be maintained in their departments and initiated in other departments in the polytechnic that were not involved in this study. On the whole, they want it integrated into the polytechnic structure to enable teacher learning and collaboration. An idea that was widespread among teachers

Table 3. Challenges of working in a design team.

Challenge	TDT	Solution
Deciding on time for TDT meetings	All	Met before or after teaching periods
Workload	ETDT	Adjustment of schedules
Consensus-building (only initial)	All	Harmony and compromises over time
Dominance by older or more experienced teacher (only initial)	PTDT	Prompted by colleagues amicably
Department standstill for TDT meetings	ETDT	Met before or after teaching periods
Some teachers' having their teaching period(s) coinciding with times for TDT industry trips	All	Teachers concerned gave group assignment to their students within the period when the former were visiting industry

was the need to involve industry representatives in the course update process for their contributions. Another common suggestion was that teachers' industrial visit should be undertaken during vacation periods to avoid the obvious absence of a whole group of teachers from a department when school is in session. Teachers recommended that their industrial visits should be done on a yearly basis to keep up the momentum of their knowledge and skill update.

Discussion and conclusion

Exploring the impact of teacher design teams, as a professional development arrangement, on polytechnic teachers' knowledge and skills has been the focus of this study. The TDT concept, in this initiative, aimed to provide a secure space where teachers' creativity could flourish and where dialogue on teacher learning and curriculum design could be reconsidered and reflected upon. The teachers' enumeration of their experiences with working in TDTs has informed this research. Notable were the commitment and enthusiasm teachers showed during TDT activities and tasks. They benefited from collaboration in TDTs as it stimulated their learning and this confirms the findings of Billett (2006) and Wenger (2003) that individual learning in the social context gives them the opportunity to expand their repertoire of experience. Teacher learning and professional development was impressive during collaborative curriculum design, as similarly was the case in the studies of Ball and Cohen (1996), Deketelaere and Kelchtermans (1996), Mishra *et al*. (2007) and Penuel *et al*. (2007). Teachers were able to enrich their courses, which impacted positively on their knowledge of subject matter and teaching – which is akin to the findings of Nieveen *et al.* (2005), who used TDTs as part of school-based curriculum innovation that brought teachers to the forefront of curriculum improvement and generated teacher ownership, commitment and professional development. Embarking on industrial attachment as planned and executed in TDT culminated in teachers updating their knowledge and skills by getting abreast with some technological advancement in industry, as likewise identified by Cort *et al*. (2004) that up-to-date vocational skills and knowledge is one of the competencies needed by TVET teachers.

The results of this case study were limited to data gathered and analysed from one polytechnic. The relatively small sample size needs to be taken into consideration and limits the simple generalisation of the results. More research, within poly-

technics and other TVET institutions, is needed to validate these findings. In addition, this study described how teachers learned through their experiences with TDT to enhance their knowledge and skills; it did not intend to determine the degree of its effect on students' achievement. For a TVET institution in a developing country, it appears that the number of master's degree holders, as in this study, is quite high; the reason being that degree programmes (Bachelor of Technology) are now being offered in the polytechnics. Thus a postgraduate degree is the minimum academic qualification for teaching undergraduate programmes. Furthermore, teachers with postgraduate qualifications are promoted to the professional rank of lecturer and are better remunerated than those without postgraduate qualifications. These two reasons outlined could be contributing factors to motivate the polytechnic teachers to acquire postgraduate degrees.

Collaboration among teachers in TDTs was enhanced and opened up the opportunity for dialogue on their subject matter, discussions on what should be taught, brainstorming on relevant information from industry and brought teachers with varied experiences and ages to a level of thinking and cohesion. Collaboration thus enabled teacher interdependency and interaction. Likewise in the study of Handelzalts (2009), it was found out that the more teachers depended on each other through collaboration, the more potential the interaction had for teacher learning. Similar to the findings of this study are evidences from a wide range of research (Clement and Vanderberghe 2000, Putnam and Borko 2000, McCotter 2001, Borko 2004, Erickson *et al*. 2005, Lumpe 2007, Handelzalts 2009) suggesting that professional development interventions which make extensive use of teacher collaboration are particularly successful in supporting teacher learning. The cohesion found among team members in this study confirms the findings of Penuel *et al*. (2009) that multiple participants in professional development from a single school helps to build trust and support relationships. Teacher learning impacted positively in their classroom practices as a result of redressing particular challenges in their courses. This was evident in the teaching tryout where students appreciated the knowledge they acquired, a finding similar to that of Millar *et al*. (2006), whose studies with TDTs to develop research-based classroom materials resulted in increased student motivation. While the sense of ownership in a relevant course swelled up confidence in individual teachers, their working in a TDT throughout the intervention noticeably appeared to be a worthwhile approach to teamwork for them to update their knowledge and skills and update their courses, as found in the studies of Millar *et al*. (2006), Nieveen *et al.* (2005) and Simmie (2007). Despite the few initial challenges that teachers encountered in TDTs, such as consensus-building and combining TDT activities with already heavy teaching workloads, their teamwork to advance ideas had enormous returns, making it a promising strategy for their knowledge update.

In conclusion, findings suggest that TDT is a useful venture for the updating of teachers' knowledge and skills in polytechnics. Findings from this study provided evidence that the TDT approach in professional development can foster teacher learning and collaboration. The study provided new lenses for professional development activities that employ teamwork for teacher learning and change. The findings on the TDT approach to change teacher practices and beliefs with regard to improving their knowledge and skills have important implications for teacher professional development. It becomes evident that in professional development it is worthwhile to engage teachers in teamwork to rigorously plan and implement their own learning.

In light of this, it can be concluded that teachers' knowledge and skills update through industrial attachment is a *sine qua non* for professional competence in the TVET sector and can be said to be better approached through teamwork as in TDTs.

From the findings in this study, it is recommended that for TDTs to be more robust to carry out their activities, teachers must see themselves and each other as learners in the team, which may to a large extent encourage tolerance and mutual understanding and reduce dominance. Also, in order not to evade the goal of learning by design, it is necessary for teachers to understand the principles of developing themselves and their courses. Furthermore, meeting regularly and varying TDT activities is likely to prevent boredom, eschew passive behaviours and encourage participation.

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