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"Conceptual Change" as a guiding principle for the professional development of teaching staff

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“Conceptual Change” as a guiding principle for the professional development of teaching staff

Abstract

This paper describes an attempt to use a conceptual change approach for the professional development of college-level teaching staff. While novice instructors often have an instructor-centered view of teaching and, consequently, use traditional teaching formats, professional development programs (PDPs) are most often based on a constructivist framework that favors student-centered learning scenarios. Prior research suggests that the development of instructors’ beliefs about teaching can be interpreted in terms of conceptual change, and that PDPs should take this perspective into account. This study documents instructors’ changes in the perception of their own teaching in the context of a professional development seminar based on conceptual change. A questionnaire was used to measure initial conceptions about teaching before participation in the PDP. The identical questionnaire was administered a second time after the seminar and again three months later. We compare different formats of the seminar as well as instructors from different academic disciplines. The focus is laid especially on instructors in STEM disciplines (Science, Technology, Engineering and Mathematics) versus non-STEM disciplines. The data obtained suggest that (1) there are differences between STEM and non-STEM instructors with respect to their initial beliefs, (2) there is noticeable development of the instructors’ conceptions about teaching and learning as a result of participation in the program, and (3) different formats of the same program may display widely differing effectiveness.

1 Introduction

In recent years, there has been a world-wide call for a “shift from teaching to learning” in higher education.[1] This catchphrase is generally meant to propose an increased focus on the students’ perspective and their learning outcomes, and consequently a lesser focus on the instructor as a provider of information. To facilitate such a shift, many universities offer professional development programs (PDPs) for their teaching staff. However, there is little research on the effectiveness of such programs.

In this paper, we report on an investigation of the effectiveness of one particular PDP that was designed to foster the shift towards student-centered learning environments by using an approach based on the theory of conceptual change. In Section 2, we present this theoretical framework in the context of science instruction (where it has been used most often so far). The transfer of this approach to professional development programs for university instructors is motivated in Section 3, and its implementation at our institution is described in Sections 4 and 5. In Section 6, we list our research questions. Subsequently, we describe the design of our study (Section 7) and the participants (Section 8). Our results are presented in Section 9 and discussed in Section 10. We conclude with some generalizations in Section 11.

2 Conceptual change as a theory for learning in science

The conceptual change approach has emerged as an effective framework for learning, especially in science[2]. It assumes the existence of initial conceptions about the subject matter in the learners' minds. According to Vosniadou[3], "research in cognitive science, science education and developmental psychology has shown that children and also adults construct an intuitive understanding of the world which is based on their everyday experience". These concepts often differ from the currently accepted scientific explanation and tend to be resistant to change. The conceptual change theory therefore places particular emphasis on this process of change and how it can be brought about by instruction.

Elsewhere, Vosniadou[4] describes conceptual change as a "process that enables students to synthesize models in their minds, beginning with their existing explanatory framework. This is conceived to be a gradual process that can result in a progression of mental models." As the individuals' (incorrect) initial conceptions are often very robust, this process sometimes does not happen spontaneously. Posner *et al.* describe conditions that must be satisfied in order for learners to change their conceptions[5].

1. "There must be dissatisfaction with the existing conceptions."
2. "A new conception must be intelligible."
3. "A new conception must appear initially plausible."
4. "A new concept should […] have the potential to be extended."

These conditions serve as a basis for devising strategies for how incorrect conceptions can be replaced by new and scientifically correct ones. Most importantly, learners' naive theories need to be taken into account. Some strategies therefore begin by triggering the learners' prior conceptions and allowing them to reflect on their thinking. Next, students are provided with contrasting evidence to generate a contradiction to their former naïve theories. In essence, the conceptual change framework suggests inducing a *cognitive conflict* between an individual's ideas and contrasting evidence.

Research has shown that in science such instructional strategies are effective in changing students' ideas. For example, Hake[6] showed that student-centered learning methods improve conceptual understanding more than traditional learning methods. In this manner, conceptual change has served as an extremely helpful methodological framework in the teaching of STEM disciplines. This result suggests that a conceptual change approach to the professional development of teaching staff (where naïve conceptions about learning need to be overcome) may be worth exploring.

3 Conceptual change approach for the professional development of college-level teaching staff

Motivated by the findings above, this paper describes an attempt to use a conceptual change approach for the professional development of college-level teaching staff. Similarly to students holding alternative ideas of scientific concepts, many novice instructors hold beliefs about teaching that are in contradiction to the framework that the professional development programs are intended to foster. Specifically, instructors often have an instructor-centered view of teaching according to which the principal function of the instructor is to convey knowledge and, consequently, they use traditional teaching formats such as lectures or problem-solving demonstrations.

By contrast, most professional development programs intend to convey a radically different view on teaching and learning, which may be best described by the term "constructivism". Constructivism states that learning is an active process during which every individual "constructs" her or his understanding of the subject matter in question. According to Biggs[7], this implies that teaching should be seen "not [as] a matter of transmitting [knowledge] but engaging students in active learning, building their knowledge in terms of what they already understand." This view on teaching and learning is referred to as "student-centered".

(Incidentally, the above quote by Biggs also hints at the connection of the conceptual change theory to constructivism as an underlying framework of learning. For us, this connection serves as an additional motivation to adopt a conceptual change view for the design of a PDP for college-level instructors.)

Staff developers, however, observe that participants in PDPs tend to hold on to their instructor-centered teaching approach even after being exposed to alternative theories about teaching. Ho[9] describes that "in many cases, participants query the feasibility of the methods presented, defend the methods that they are currently using, apply new methods mechanically, or modify methods which are meant to facilitate student learning into a didactic transmission mode." Furthermore, Pundak[10] states that "although there is clear evidence for the benefits of active learning, most lecturers in higher education still adhere to traditional teaching methods."

Nevertheless, Kember[11] described that it is possible to change these beliefs. There can be a development from teacher-centered to student-centered concepts among higher education teaching staff. According to Kember, this development of instructors' beliefs about teaching (if successful) closely mirrors the conceptual change model. Following these results, Ho[6] has suggested and implemented an approach for professional development that is based on the conceptual change theory (described in the previous section). The approach suggested by Ho contains four separate elements, each of which may occur more than once in an actual PDP. These are presented in Table 1.

Table 1: Elements of conceptual change approach for teaching staff development by Ho[6]

Self-awareness (self-reflection)	Participants "undergo self-reflection and clarify personal conceptions"
Confrontation	Participants "are brought to realize possible inadequacies in their existing conceptions and/or teaching practices and thus create an awareness for the need to change"
Exposure	Workshop facilitator "provide[s] a direction and a model for improvement"
Commitment building	Workshop facilitator "encourage[s] teachers to engage in changes and development"

In the following sections, we describe a professional development program that implements Ho's concept in order to foster a constructivist framework and student-centered learning scenarios, and present an investigation of its effect on the instructors' conceptions of teaching.

4 The New Faculty Workshop at the *DiZ – Center of Teaching and Learning in Higher Education*

For 20 years, the *DiZ – Center of Teaching and Learning in Higher Education* has offered a four-day professional development workshop for new faculty at the Bavarian Universities of Applied Sciences. These instructors teach in any of the bachelor and master programs offered by the respective institutions, which are academic in focus but more application oriented than traditional universities. While work experience in industry is required to obtain a professorship at a University of Applied Sciences, prior teaching experience is not. To remediate this situation, the *DiZ – Center of Teaching and Learning in Higher Education* was founded as a center of teaching and learning in higher education. Its task is to offer special professional development programs for new faculty staff.

Unlike at most other universities in Germany, instructors at these institutions are required to attend a professional development workshop during their first three semesters of college-level teaching. The course considered in our paper is often the first course on teaching and learning that they attend.

In the early days of the *DiZ*, only five or six workshops were offered each year. They were taught by experienced peers (college-level instructors) with a passion for teaching but no specific pedagogical training. While there existed broad agreement on the content of the PDP, namely practicing new teaching methods and standards for lecturing, there was no pre-determined curriculum. Moreover, a uniform theoretical foundation was lacking, and each facilitator emphasized different pedagogical models.

Starting around the year 2008, the number of new faculty increased substantially, thus making it necessary to offer more than twice as many workshops per year. This required the use of a greater number of facilitators, and hence the development of a uniform curriculum in order to offer consistent workshops. The necessary restructuring of our program provided us with the opportunity to adopt (1) constructivism as the underlying theoretical framework and (2) conceptual change as our approach to preparing the participants for their own teaching. We designed our curriculum to focus on the following questions:

- What is constructivism?
- What are student-centered learning methods and how do they work?
- Why is it important to specify learning goals?
- How do novice instructors think about teaching?

The process of redesigning our program was completed by 2010. Since then, there are currently between 15 and 20 such workshops offered per year. Each course is attended by twelve participants from different fields, including STEM disciplines (in our case: Computer Science, Engineering and Technology, and Science) and non-STEM disciplines (Business Studies, Social Work, Architecture and Design, and Journalism).

Since the introduction of the redesigned PDP, participants often expressed their preference for shorter workshops as an alternative to the existing four-day format. A modified program was therefore designed, consisting of two two-day workshops, separated by eight weeks to allow the participants to practice alternative teaching methods in their own courses in the meantime. Beginning in 2014, both types of seminars (henceforth denoted as "1x4" and "2x2") have been offered in parallel.

5 Implementation of the conceptual change approach in the New Faculty Workshop

Below, we illustrate how the single elements of a conceptual change curriculum described by Ho are implemented in our staff development program:

Figure 1: Simplified structure of the conceptual change elements in the PDP. (Some of the elements are visited more than once.)

Self-reflection 1:

Before the beginning of the workshop, all participants are asked about their concept of teaching. Moreover, they are requested to describe their preferred way of learning. The participants' answers are collected via an online learning platform and later made visible (in anonymous form) to all participants as they begin the workshop. They are not commented on or discussed in the group until later in the workshop.

Exposure 1:

The first day of face-to-face instruction begins with an input about constructivism and a discussion about the implications of this theory for effective teaching practices.

Self-reflection 2:

The participants report on their own teaching practice and experience. Usually, there is an awareness that there may be other ways of teaching that achieve much deeper learning and understanding. However, the participants find many reasons why they continue to use traditional teaching methods and why they are not able to use other learning methods instead.

Exposure 2:

The participants get the opportunity to experience alternative (i.e., active) methods of teaching and learning as the workshop instructors use these methods to "present" workshop content. Each instance of a new method is followed by a group discussion on its advantages, possible implementation, and important aspects to keep in mind.

Confrontation 1:

In the group, the new experience with the alternative methods is discussed. Frequently, the participants question the effectiveness of the experienced learning methods. For example, they dispute the students' willingness to mentally engage with the course content and suspect students to discuss other matters. However, the participants also understand the basic premise of constructivism and recognize the limitations on the effectiveness of traditional teaching methods. Figuratively speaking, they move back and forth between their current, mostly traditional way of teaching and alternative conceptions of teaching and learning, thereby beginning to experience a cognitive conflict.

Self-reflection 3:

The previous unit is extended on the third day of the workshop by asking the participants to recall negative and positive examples of the teaching they have experienced during their own studies. Moreover, the participants reflect on how these experiences affect their own day-to-day teaching practice.

Confrontation 2:

The participants compare their answers to the previous questions with each other and to the initial statements about their concept of teaching and their own learning experience. Thereby, they are given an opportunity to observe contradictions between their experiences as learners, which mostly reflect a learner-centered approach, and their own practice as teachers, which strongly mirrors a teacher-centered approach. The highly emotional discussion among the workshop participants that follows these tasks can be interpreted as evidence for the ongoing cognitive conflict.

Exposure 3:

A method of defining and classifying learning goals (similar to that proposed by Bloom[12]) is presented and their implications for the required teaching methods (following the model of constructive alignment by Biggs[13]) are discussed. The participants then define learning goals for a sample lesson and discuss these with the workshop instructors. Many of the learning goals found are anchored in deep learning and understanding. However, if made explicit at all, the chosen learning methods are most often traditional ones.

Commitment building:

As their last activity on day 3, the participants each plan a section of their class using some of the proposed methods and present their plan to a colleague to obtain feedback. On day 4, the results of this process are demonstrated in 10-minute micro-teaching units by each of the participants, immediately followed by feedback from the entire group. As a result, the participants obtain the impression that the proposed methods can actually work in their own teaching.

6 Research question

In this study, instructors' changes in the perception of their own teaching are documented in the context of the professional development program described above. The study aims to answer the following research questions:

1. Are initial conceptions about teaching held by novice instructors in STEM fields different from those held by instructors in other disciplines?
2. How are the conceptions about teaching influenced by the participation in a professional development program that has been developed with a focus on conceptual change?
3. Do the two formats of the professional development program differ in their effectiveness, and are they more effective than the previous program (which had a lesser focus on conceptual change)?
4. How does subsequent teaching experience over the course of several months further affect these conceptions?

7 Design of research study

In this study, instructors' conceptions about teaching are measured using the *Approaches to Teaching Inventory (ATI)*, a 16-item questionnaire developed by Trigwell and Prosser[14]. According to the authors, the questionnaire contains two different scales: One is "indicating an information transmission [or] teacher focused approach to teaching, and the other a conceptual change [or] student focused approach." (Henceforth, we will refer to these two scales as "TF" and "SF" scales.) The appropriateness of the instrument is asserted by the authors. "The questionnaire was specifically designed for a study of approaches to teaching in first-year university science classes." The authors' intention was to develop an instrument that gives participants of professional development programs in higher education the opportunity to reflect on their teaching.

Each item of the inventory consists of a statement that expresses a certain aspect of a teacher-centered or student-centered approach to teaching and learning to which agreement can be expressed on a Likert scale from one to five (1 = *Only rarely* to 5 = *almost always*). For a literal reproduction of the ATI in the English original, please consult the Appendix.

Over the course of time, Trigwell and Prosser modified the ATP. They changed the wording of some of the items and added new ones. The ATI-R, as the revised test is now known, is a 22-item questionnaire (published in 2004). In 2005, when we started our investigation (prior to redesigning the PDP), the ATI-R was not known to us and therefore the 16-item survey was used. This first effort of investigating the program ended in 2007. A more recent investigation, aiming to compare the effects of the redesigned and original programs, began in February of 2014 and is still in progress. An additional reason to revisit and continue the initial study was to compare the effectiveness of the two formats that are now in use. The same questionnaire (i.e., the original ATI) is used as in the initial study.

In this study, we use the ATI to measure initial conceptions about teaching before participation in the four-day professional development program (t_1). The identical questionnaire is administered a second time at the end of the seminar (t_2), and again three months later (t_3). As the return rate for questionnaires at t_3 has been rather low ($\approx$ 35%) and self-selection effects are very likely, we restrict the discussion to the initial conceptions and changes during the seminars.

8 Participants

In the first part of the investigation (from July 2005 to February 2007), there were 146 participants in the workshops. All of these completed the survey at the beginning of the workshop. One person did not indicate their discipline. As our study focuses on instructors in STEM vs. non-STEM disciplines, we removed this questionnaire and analyzed the responses of the remaining N = 145 participants. The two groups consisted of 61 (non-STEM) and 84 (STEM) instructors.

Between February 2014 and February 2015, a total of 192 instructors participated in the workshops. Of these, 179 completed the survey at the beginning of the workshop. Twenty-two (22) participants did not indicate their discipline. We therefore removed these entries and analyzed the responses of the remaining N = 157 participants. The two groups consisted of 68 (non-STEM) and 89 (STEM) instructors. Their distribution across individual fields is shown in Table 2.

Table 2: Overview of participants from non-STEM and STEM disciplines

Discipline	Field	2005 – 2007	2014 – 2015
Non-STEM	Business Studies	41	48
	Social Work	13	13
	Architecture & Design	12	0
	Journalism	2	0
	Subtotal	***68***	***61***
STEM	Computer Science	8	20
	Engineering & Technology	60	53
	Science	21	11
	Subtotal	***89***	***84***
	Total	***157***	***145***

In total, 302 individuals began participation in our study ($N = 302$ at t_1). Not all of these took the survey at the end of our workshops ($N = 276$ at t_2), and even fewer took the survey after three months ($N = 106$ at t_3) as indicated in Table 3. Moreover, not all participants answered every item on each questionnaire. As a result, the number of answers to any single item varies and is not always equal to the number of questionnaires collected.

Table 3: Overview of participants from non-STEM and STEM disciplines for t_1, t_2 and t_3

Discipline	Field	N (at time 1)	N (at time 2)	N (at time 3)
Non-STEM	Business Studies	89	81	33
	Social Work	26	25	11
	Architecture & Design	12	8	0
	Journalism	2	2	0
	Total	***129***	***116***	***44***
STEM	Computer Science	28	26	13
	Engineering & Technology	112	105	39
	Science	33	29	10
	Total	***173***	***160***	***62***
	Absolut Total	***302***	***276***	***106***

9 Results

Results pertaining to research question 1:
Are initial conceptions about teaching held by novice instructors in STEM fields different from those held by instructors in other disciplines?

Answers to the survey before participation in the workshops showed significant differences between instructors in non-STEM and STEM disciplines on eight of the 16 items. With one exception, these were significant at the 1% ($p = .01$) level. The remaining eight items all were not nearly significant ($p > .15$). These results are shown in Table 4, which includes abbreviated descriptions of the items.

Seven of the eight items that showed significant differences between non-STEM and STEM instructors belong to the "conceptual change" or "student focus" (SF) scale of the instrument. In fact, except for Item 15, which concerns note taking by students, these items make up the entire SF scale. Conversely, only one of the items yielding a significant difference is part of the "information transmission" or "teacher focus" (TF) scale of the instrument. Incidentally, this item (Item 11) also refers to note taking (by stressing its importance as a reason for lecturing).

Table 4: Survey results before workshop for non-STEM vs. STEM instructors (2005-2007 and 2014-2015 workshops)

Item	Topic	Non-STEM Mean (SD)	STEM Mean (SD)	*t*	*df*	*p*
1	Designing teaching with assumption that students have little knowledge (TF)	3.57 (.828)	3.54 (.775)	.271	299	.787
2	Importance of complete description of objectives for exam (TF)	3.23 (1.029)	3.35 (.957)	- 1.094	299	.275
3	**Trying to develop a conversation with students (SF)**	**4.42 (.778)**	**3.92 (.943)**	**4.901**	**300**	**.000**
4	Importance of presenting a lot of facts (TF)	2.81 (.985)	2.90 (1.124)	- 0.770	300	.442
5	**Assessment as opportunity to reveal changed conceptual understanding (SF)**	**3.78 (0.972)**	**3.18 (1.070)**	**4.944**	**294**	**.000**
6	**Allowing time for students to discuss difficulties (SF)**	**3.05 (1.239)**	**2.68 (1.191)**	**2.681**	**300**	**.008**
7	Concentrating on covering information from textbook (TF)	3.31 (1.044)	3.47 (.937)	-1.381	300	.168
8	**Encouraging students to restructure knowledge (SF)**	**4.37 (.791)**	**3.99 (.924)**	**3.733**	**300**	**.000**
9	**Using difficult or undefined examples to provoke debate (SF)**	**3.67 (1.018)**	**3.30 (1.179)**	**2.855**	**299**	**.005**
10	Structuring subject to help students pass exam (TF)	3.97 (.918)	3.91 (.975)	0.560	299	.576
11	**Importance of lectures for providing students with notes (TF)**	**2.05 (.934)**	**2.34 (1.109)**	**- 2.404**	**299**	**.017**

12	Providing only information needed to pass exams (TF)	3.59 (1.058)	3.51 (1.009)	0.623	300	.534
13	Obligation to answer any question that students ask about subject (TF)	3.20 (1.180)	3.36 (1.083)	- 1.184	299	.238
14	**Allowing time for students to discuss their changing understanding of subject (SF)**	**3.83 (.977)**	**3.31 (1.061)**	**4.372**	**279**	**.000**
15	Advantage of students' preparing own notes over copying those of instructor (SF)	3.48 (1.004)	3.33 (1.035)	1.200	297	.231
16	**Importance of time for questioning students' ideas (SF)**	**2.58 (.924)**	**2.18 (.886)**	**3.758**	**295**	**.000**

Scale: 1 = *Only rarely* to 5 = *almost always.* Significant results ($p < 0.05$) are shown in bold.

On all of the "significant" items representing a student-focused approach, the STEM instructors indicated *lesser* agreement on average than the non-STEM instructors. On the "significant" item representing a teacher-focused approach, the STEM instructors indicated *greater* agreement. These results indicate that STEM instructors in our program generally view teaching more as an act of transmitting information than instructors in other disciplines.

Separate comparison of non-STEM *vs.* STEM instructors for the 2005-2007 and 2014-2015 workshops yields slightly different sets of "significant" items. However, the intersection of these sets consists of Items 3, 5, 8 and 14 (which all belong to the SF scale). We therefore interpret this result to confirm our finding of the general difference in approach between STEM and non-STEM instructors.

Results pertaining to research question 2:
How are the conceptions about teaching influenced by the participation in a professional development program that has been developed with a focus on conceptual change?

Comparing instructors' responses before and after participation in the PDP described in Section 4 on an item-by-item basis shows significant differences for seven of the 16 items. Four of these (Item 5, 6, 9, and 16) belong to the SF scale and yield *greater* agreement with a student-focused approach after the seminar, consistent with the aim of the program. The remaining three "significant" items (Item 2, 11, and 13) belong to the TF scale. Agreement on Item 2 increases and can be interpreted as an increased recognition of the importance of well-defined learning outcomes as stressed in the seminar. While the increased agreement on Item 11 (importance of lecturing for note taking) is difficult to interpret, the decrease in agreement on Item 13 (obligation to answer any question) can be seen as a positive outcome of the seminar. It is consistent with the intended "shift from teaching to learning" as illustrated by the often-quoted phrase "From the sage on the stage to the guide on the side"[15].

Table 5: Changes in survey results from before workshop to after workshop (Instructors of all disciplines, workshops 2014-2015)

Item	Topic	*Before* Mean (SD)	*After* Mean (SD)	*t*	*df*	*p*
1	Designing teaching with assumption that students have little knowledge (TF)	3.53 (.832)	3.53 (.841)	- .091	136	.928
2	**Importance of complete description of objectives for exam (TF)**	**3.34 (.978)**	**3.80 (.990)**	**- 4.414**	**137**	**.000**
3	Trying to develop a conversation with students (SF)	4.12 (.875)	4.28 (.891)	- 1.817	136	.071
4	Importance of presenting a lot of facts (TF)	2.96 (1.063)	2.97 (.935)	- .070	137	.945
5	**Assessment as opportunity to reveal changed conceptual understanding (SF)**	**3.49 (1.053)**	**3.72 (.947)**	**- 2.232**	**133**	**.027**
6	**Allowing time for students to discuss difficulties (SF)**	**2.84 (1.160)**	**3.41 (1.079)**	**- 5.937**	**137**	**.000**
7	Concentrating on covering information from textbook (TF)	3.44 (.989)	3.39 (.992)	- .576	137	.566
8	Encouraging students to restructure knowledge (SF)	4.09 (.875)	4.21 (.950)	- 1.248	137	.214
9	**Using difficult or undefined examples to provoke debate (SF)**	**3.34 (1.064)**	**3.70 (.971)**	**- 3.546**	**137**	**.001**
10	Structuring subject to help students pass exam (TF)	3.96 (.899)	3.94 (.918)	- .248	137	.804
11	**Importance of lectures for providing students with notes (TF)**	**2.25 (1.027)**	**2.53 (1.044)**	**- 3.285**	**136**	**.001**
12	Providing only information needed to pass exams (TF)	3.61 (1.014)	3.46 (.975)	1.727	137	.086
13	**Obligation to answer any question that students ask about subject (TF)**	**3.44 (1.021)**	**3.13 (1.098)**	**3.629**	**135**	**.000**
14	Allowing time for students to discuss their changing understanding of subject (SF)	3.50 (1.058)	3.99 (1.032)	- 1.459	136	.147
15	Advantage of students' preparing own notes over copying those of instructor (SF)	3.40 (.981)	3.55 (1.007)	- 1.745	136	.083
16	**Importance of time for questioning students' ideas (SF)**	**2.41 (.908)**	**2.59 (.933)**	**- 2.117**	**134**	**.036**

Scale: 1 = *Only rarely* to 5 = *almost always*. Significant results ($p < 0.05$) are shown in bold.

Results pertaining to research question 3:
Do the two formats of the professional development program differ in their effectiveness, and is either more effective than the previous program (which had a lesser focus on conceptual change)?

Comparing instructors' responses before and after participation in the PDP separately for the two formats (one four-day seminar [1x4] or two two-day seminars [2x2]) yields noticeable differences concerning the number of items with significant changes. Whereas the 1x4 format results in significant changes for nine items (including six from the SF scale), the 2x2 format only shows significant changes for two items (with only one from the SF scale). Table 6 shows these results by listing the average changes (post- minus pre-workshop), their standard deviations, and the degrees of freedom and *p* value of the *t*-test for paired samples.

Table 6: Changes in survey results from before workshop to after workshop by workshop format (all disciplines, 2014-2015)

Item	Topic	1x4 Format			2x2 Format		
		Change Mean (SD)	*df*	*p*	Change Mean (SD)	*df*	*p*
1	Designing teaching with assumption that students have little knowledge (TF)	.013 (.899)	78	.901	- .034 (1.008)	57	.795
2	Importance of complete description of objectives for exam (TF)	**- .525 (1.292)**	**79**	**.000**	**- .362 (1.103)**	**57**	**.015**
3	Trying to develop a conversation with students (SF)	- .177 (.844)	78	.066	- .155 (1.348)	57	.384
4	Importance of presenting a lot of facts (TF)	.150 (1.233)	79	.280	- .224 (1.185)	57	.155
5	Assessment as opportunity to reveal changed conceptual understanding (SF)	**- .263 (1.147)**	**75**	**.049**	- .172 (1.187)	57	.273
6	Allowing time for students to discuss difficulties (SF)	**- .688 (1.132)**	**79**	**.000**	**- .414 (1.124)**	**57**	**.007**
7	Concentrating on covering information from textbook (TF)	- .188 (.969)	79	.087	- .138 (1.099)	57	.343
8	Encouraging students to restructure knowledge (SF)	**- .250 (.879)**	**79**	**.013**	.086 (1.174)	57	.578
9	Using difficult or undefined examples to provoke debate (SF)	**- .512 (1.201)**	**79**	**.000**	- .138 (1.115)	57	.350
10	Structuring subject to help students pass exam (TF)	- .050 (.899)	79	.620	.121 (1.186)	57	.441
11	Importance of lectures for providing students with notes (TF)	**- .350 (.943)**	**79**	**.001**	- .193 (1.109)	56	.194
12	Providing only information needed to pass exams (TF)	.150 (.813)	79	.103	.138 (1.191)	57	.382
13	Obligation to answer any question that students ask about subject (TF)	**.418 (.928)**	**78**	**.000**	.175 (1.120)	56	.242

14	Allowing time for students to discuss their changing understanding of subject (SF)	**- .278 (1.085)**	**79**	**.025**	.017 (1.395)	57	.925
15	Advantage of students' preparing own notes over copying those of instructor (SF)	- .190 (.935)	78	.075	- .103 (1.150)	57	.496
16	Importance of time for questioning students' ideas (SF)	**- .209 (.888)**	**77**	**.045**	- .158 (1.177)	56	.316

Scale: 1 = *Only rarely* to 5 = *almost always*. Significant results ($p < 0.05$) are shown in bold.

Considering the average changes for the two formats for various items indicates that lack of significance for the effects of the 2x2 workshop is not mainly due to the smaller number of participants. However, in order to investigate the effects of the two seminars further, in particular with respect to the instructor disciplines (resulting in even smaller numbers of entries) we computed an overall "student-focus score" by summing the scores of the eight SF items.

Results from this analysis again show that the changes in student-centered teaching attitudes differ between the two formats of the redesigned program and between the previous and redesigned program (Table 7). Whereas the changes from before to after the workshop (as measured by the overall student-focus score) are highly significant for both the previous version and the redesigned program in the 1x4 format, those changes lack significance for the 2x2 format. Beyond mere significance, it is now possible to differentiate the effectiveness of the previous version and the 1x4 format by considering effect sizes. Calculating the ratio of the change to its standard deviation, we obtain effect sizes of 0.42 for the previous version and of 1.03 for the 1x4 format of the redesigned program. Froyd[16] (as quoted in Deslauriers et al.[17]) has found that science and engineering classroom studies generally report effect sizes of less than 1. We therefore consider an effect size of (slightly) more than as a sign of the success of the redesigned program in this format.

(It may be noted that the mean SF score before participation in the program is higher than for the other two groupings. This indicates a self-selection effect in the sense that novice STEM instructors participating in the 2x2 workshops tend to have a more student-centered view of teaching and learning already at the beginning of the program. However, when comparing to data from non-STEM instructors [not shown here], who tend to have higher initial SF scores than STEM instructors, it becomes evident that there is no ceiling effect. In other words, non-STEM instructors in the 1x4 format on average achieve higher SF scores than STEM instructors in the 2x2 format, both before and after participation in the program.)

Table 7: Changes in overall student-focus score from before workshop to after workshop by workshop version and format (STEM disciplines only)

	Before Mean SF score (SD)	*After* Mean SF score (SD)	*Change* (SD)	*t*	*df*	*p*
Previous version	25.87 (4.780)	27.64 (4.939)	1.77 (4.214)	- 3.678	76	.000
1x4 format	24.66 (3.885)	28.00 (4.793)	3.34 (3.240)	- 6.358	37	.000
2x2 format	27.28 (4.199)	28.53 (5.369)	1.25 (6.096)	- 1.230	35	.227

Results pertaining to research question 4:
How does subsequent teaching experience over the course of several months further affect these conceptions?

As the return rate for questionnaires at t_3 has been rather low (≈ 35%) and self-selection effects are very likely, we decided not to pursue this question any further at this time.

10 Discussion

Results of our study indicate that instructors in STEM disciplines have a less student-centered view of teaching and learning than instructors in non-STEM disciplines. (Instructors' initial conceptions show little difference across disciplines on teacher-centered items.) As the research methods used here, however, do not allow us to identify specific reasons for this difference, we may only speculate what these are. Traditional instruction in STEM disciplines (i.e. the kind of instruction that the STEM participants in our PDP most likely have experienced in their own education) heavily emphasizes solving quantitative problems. As such problems do not naturally invite much discussion, items that relate to intellectual debate and questioning show little appeal for many STEM instructors, who may therefore need additional help in seeing the value of discussions and overcoming such beliefs.

Our data also suggest that our PDP has some positive effects. In particular, a strengthening of the participants' responses on student-centered items indicates that the shift in attitudes that is desired does actually occur. Considering the teacher-centered items, we also observe changes in some of those. A closer look suggests that several of these reflect an intended development, either by a strengthened support for favorable statements (such as a focus on learning goals) or by a weakened support for unfavorable statements (such as a focus on the instructor as an unfailing "fountain" of information).

There is strong evidence for differences that exist between the two formats of the redesigned workshop. First, this can be seen by a count of items that show significant changes from before to after participation in the program. Whereas in the 1x4 format there are nine such items (including six on the student-focus scale), there are only two in the 2x2 format (with only one on the student-focus scale). Secondly, the computation of an overall student-focus score shows a highly significant change for the 1x4 format as opposed to no statistical significance for the change due to the 2x2 format.

Two reasons appear likely to account for these differences: First of all, the 1x4 format may result in a closer connection between participants, leading in turn to more profound discussions about their ideas and experiences. Moreover, there is one adaptation to the course content that has been made in designing the 2x2 workshop format. The units *Self reflection 3* and *Confrontation 2,* as described in Section 4 above, originally scheduled for the morning of Day 3, have been replaced by a unit that allows participants to exchange their experience with the new teaching methods proposed in the first half of the workshop. The data obtained from the survey suggest that this well-intended modification has de-emphasized the confrontation stage and thereby has reduced the overall impact of the program.

11 Conclusions

The conceptual change framework has proved to be a helpful guiding principle for the design and assessment of professional development programs. In particular, it helped define a coherent structure for the New Faculty Workshop at *DiZ – Center of Teaching and Learning in Higher Education* that could be followed by different workshop instructors.

Using the ATI instrument by Trigwell and Prosser, we were able to show that a conceptual change approach, if carefully implemented, can result in substantial changes in the participants' attitudes towards teaching and learning. Moreover, the instrument helped in identifying a critical element of the New Faculty Workshop whose omission in a modified format most likely resulted in a substantially reduced effectiveness.

Generalizing from our experience, we have the following recommendations for other providers of professional development programs for college-level instructors.

1. New PDPs should be designed with a focus on conceptual change and existing programs should be checked for their agreement with such an approach.
2. Great care should be taken in allowing several instances of the essential elements of a conceptual change process, i.e. *self-reflection* and *confrontation*.
3. A workshop format that allows for several days of uninterrupted engagement with different views on teaching and learning may be superior to formats that are spread out over multiple meetings.

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Appendix

APPROACHES TO TEACHING INVENTORY

This inventory is designed to explore the way that academics go about teaching in a specific context or subject. This may mean that your responses to these items may be different to the responses you might make on your teaching in other contexts or subjects.

Please describe the context here: . . . .

For each item please circle one of the numbers (1-5). The numbers stand for the following responses:
1 - this item was **only rarely** true for me in this subject.
2 - this item was **sometimes** true for me in this subject.
3 - this item was true for me **about half the time** in this subject.
4 - this item was **frequently** true for me in this subject.
5 - this item was almost **always** true for me in this subject.

Please answer each item. Do not spend a long time on each: your first reaction is probably the best one.

		only rarely				almost always
1	I design my teaching in this subject with the assumption that most of the students have very little useful knowledge of the topics to be covered.	1	2	3	4	5
2	I feel it is important that this subject should be completely described in terms of specific objectives relating to what students have to know for formal assessment items.	1	2	3	4	5
3	In my class/tutorial for this subject I try to develop a conversation with students about the topics we are studying.	1	2	3	4	5
4	I feel it is important to present a lot of facts in classes so that students know what they have to learn for this subject.	1	2	3	4	5
5	I feel that the assessment in this subject should be an opportunity for students to reveal their changed conceptual understanding of the subject.	1	2	3	4	5
6	We take time out in classes so that the students can discuss, among themselves, the difficulties that they encounter studying this subject.	1	2	3	4	5
7	In this subject I concentrate in covering the information that might be available from a good textbook.	1	2	3	4	5
8	I encourage students to restructure their existing knowledge in terms of the new way of thinking about the subject that they will develop.	1	2	3	4	5
9	In lectures for this subject, I use difficult or undefined examples to provoke debate.	1	2	3	4	5
10	I structure this subject to help students to pass the formal assessment items.	1	2	3	4	5
11	I think an important reason for giving lectures in this subject is to give students a good set of notes.	1	2	3	4	5
12	When I give this subject, I only provide the students with the information they will need to pass the formal assessments.	1	2	3	4	5
13	I feel that I should know the answers to any questions that students may put to me during this subject.	1	2	3	4	5
14	Formal teaching time is made available in this subject for students to discuss their changing understanding of the subject.	1	2	3	4	5
15	I feel that it is better for students in this subject to generate their own notes rather than always copy mine.	1	2	3	4	5
16	I feel a lot of teaching time in this subject should be used to question students' ideas.	1	2	3	4	5

Thank you! **Michael Prosser and Keith Trigwell, 1996**