þÿ F u t u r e C h e m i s t r y T e a c h e r s P e r c e p t i o n s o f V o c a Relevant Learning Methods

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þÿ A L M A M A T E R S T U D I O R U M U n i v e r s i t y o f B o l o g n a
2021

þÿ P e r n a a , J & A k s e l a , M 2 0 2 1 , F u t u r e C h e m i s t r y T e a c h e r s P e r c e p t i o n
Relevant Learning Methods . in O Levrini & G Tasquier (eds) , ESERA 2019 : The Beauty
and Pleasure of Understanding: Engaging with Contemporary Challenges Through Science
þÿ E d u c a t i o n (P r o c e e d i n g s o f E S E R A 2 0 1 9) . A L M A M A T E R S T U D I O R U M
þÿ B o l o g n a , B o l o g n a , p p . 1 4 2 6 1 4 3 5 , E S E R A 2 0 1 9 , B o l o g n a , I t a l y , 2 6

http://hdl.handle.net/10138/329097

publishedVersion

FUTURE CHEMISTRY TEACHERS' PERCEPTIONS OF VOCATIONALLY RELEVANT LEARNING METHODS

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The lack of relevance is a major challenge in chemistry education. In the last two decades, a lot of research and development projects for increasing the relevancy have been conducted in all educational levels, expect in chemistry teacher education. This research is filling this knowledge gap by investigating what kind of learning methods in pre-service chemistry teacher education have high and low vocational relevance. The relevance of different learning methods included in chemistry teacher education courses are analysed by studying future chemistry teachers' perceptions. Research was carried out as a case study utilising a mixed methods approach. Data was collected via an online questionnaire. The total number of respondents was 72. According to this research, laboratory activities, teaching exercises (e.g. teaching for peers or pupils in a non-formal learning environment study visit) and discussions (e.g. group discussions) were experienced the most vocationally relevant. Writing exercises were experienced the least relevant. All highly relevant learning methods stimulated high-order thinking skills and supported collaborative learning. The level of experienced relevance was mostly intrinsic (skills and knowledge for career) and it had both present and future focus. These results can be used for developing vocationally high relevance learning methods for pre-service chemistry teacher education.

Keywords: learning method, pre-service chemistry teacher education, relevance

INTRODUCTION

The term "relevance" is often mentioned as a goal for developing educational programs, courses and learning materials. It has interested scholars over many decades, because the lack of relevance is a major challenge in science education. For example, students don't experience science relevant for their everyday lives and therefore, they don't choose a science-related career (Osborne et al., 2003; Osborne & Dillon, 2008; Sjøberg & Schreiner, 2010).

Depending on the definition, relevance has been used e.g. as a synonym for interest, describing students' perception of meaningfulness or their learning needs or a mixture of all these. (Stuckey et al., 2013) One highly citated model for defining the concept of relevance has been published by Stuckey et al. in 2013. They made a broad literature review of how the term "relevance" has been used in education. Based on their review, they formed a multidimensional relevance model that summarises central ideas from earlier literature. In Stuckey et al.'s definition, the meaning of relevance is modelled through different dimensions (personal, societal and vocational) and the relevance may be experienced as internal or external in the present moment or in the future. (see Stuckey et al., 2013)

The lack of relevance has at least two dramatic effects – a lack of applicants and a great dropout number during university studies (Hailikari & Nevgi, 2010; Heublein & Schmelzer, 2018; Hill et al., 1990; Valto & Nuora, 2019). From the perspective of chemistry studies, this means that

students don't experience chemistry as an interesting or an important subject and therefore don't choose it as their future study field. Also, from those who enrol for chemistry bachelor studies, about 30–40% of will drop out (Heublein & Schmelzer, 2018; Hill et al., 1990; Valto & Nuora, 2019). Many switch into more vocationally clearer fields like medical studies or drop out university studies altogether (Hailikari & Nevgi, 2010). The lack of relevance has led to a situation where too few young people enrol for chemistry studies and even fewer graduate, resulting a major lack of expertise. The situation is challenging because the need is massive. Chemistry is one of the world's biggest fields measured by any economical meter and provides jobs for over 15 million people (Oxford Economics, 2019).

In order to solve the relevance challenge and secure the talent pipeline from school to industry, the field is seeking answers from chemistry education research (Eilks & Hofstein, 2015). CER field has the key role in solving the relevance challenge of chemistry studies. Firstly, CER scholars develop new research-based solutions (e.g. learning materials, evaluation methods, curricula etc.) for supporting relevant chemistry education. This research area has been quite active in the recent years (see Eilks & Hofstein, 2015). Secondly, CER field educates a majority of future chemistry teachers who are introducing the field to countless children every day. According to research, teachers have a significant role in career decision making (Hill et al., 1990; Hugerat et al., 2015) and therefore, chemistry teachers are the most important group of professionals inspiring young people into the chemistry field. Even though chemistry teachers' role is crucial, there is a lack of relevance studies conducted in pre-service chemistry teacher education (see the next section for more details).

Through this research, we contribute to solving the relevance challenge by studying future chemistry teachers' perceptions of vocationally relevant learning methods (e.g. laboratory exercises, research tasks, writing assignments, learning discussions etc.). The study was directed through the following research questions: RQ1: What kinds of learning methods do future chemistry teachers consider most relevant or irrelevant for their learning and future career? RQ2: What kinds of arguments do they present for relevant and irrelevant methods? We propose that answering these questions is important for pre-service chemistry teacher education because:

1. Learning methods have a crucial role in engaging, inspiring and motivating students into chemistry learning. For example, carrying out laboratory experiments is experienced significantly more interesting than watching or planning experiments. (Bolte et al., 2013) If the most relevant and irrelevant methods can be identified, it enables developing pre-service chemistry teacher education into a more professionally relevant direction through a research-based approach.
2. Future chemistry teachers must be taught through versatile methods, because they learn how to teach and learn chemistry through those examples. Students build their professional identity around methods that they experience as supporting their own learning and use them in their future profession as chemistry teachers. (Aksela, 2010)

Our hypothesis is that methods that students find vocationally relevant, support building their chemistry knowledge, pedagogical content knowledge (PCK), professional confidence and self-efficacy. Self-confident chemistry teachers who trust their professional knowledge and skill set are one of the key solutions in solving the relevance challenge of chemistry studies.

VOCATIONAL RELEVANCE OF CHEMISTRY TEACHER EDUCATION

In Stuckey et al.'s (2013) relevance model, the vocational dimension refers to knowledge, skills and formal certificates that prepare or enable succeeding in the future profession (see Table 1). Analysed from the perspective of pre-service chemistry teacher education, the vocational dimension can be focused on many different skills or knowledge components. This is due to the diverse structure of the degree. The structure varies from country to country, but e.g. in Finland, training lasts five years including chemistry studies (1st teaching subject – two years), 2nd teaching subject (e.g. mathematics, physics, biology, computer sciences – one year), pedagogy (including teaching practice training – one year), chemistry education and its research (e.g. bachelor's and master's theses – one year). (Aksela, 2010) In this section, we don't address vocational relevance aspects related to chemistry subject studies, 2nd teaching subject or pedagogical studies, because our data is collected during chemistry education courses and targeted on learning methods included on those courses.

Table 1. Examples of vocational dimension in different levels and states (Stuckey et al., 2013).

Vocational Dimension	**Intrinsic**	**Extrinsic**
Present	Orientation about potential careers for chemistry teachers.	Passing exams for getting the degree.
Future	Knowledge, skills and networks that secure getting a satisfactory job.	Contributing to society's economic wellbeing.

We have viewed literature through the above limitations. Our review indicates that vocational relevance of teacher education in general has been studied extensively (see e.g. Sheridan, 2013), but there is a lack of studies conducted in chemistry teacher education. Fundamentally, the vocational perspective of teacher education is clear. Teacher training offers a clear pathway to a specific teaching profession. Therefore, also the vocational relevance of chemistry teacher education itself is clearer compared to e.g. the profession of a chemist. For example, Ogunde (2017) found that students mainly apply into chemistry BSc programs because they are interested in chemistry. Ogunde argues that undergraduate students see chemistry studies as a possibility for many kinds of careers, but only few have an accurate career objective.

CER field has been active in developing the relevance of chemistry education in all education levels except in chemistry teacher training (Eilks & Hofstein, 2015). Scholars have been developing e.g. authentic research-based learning environments for supporting the science career choice (e.g. Nuora & Välisaari, 2018; Veale et al., 2018) or approaching the relevance issue through a specific subject like e.g. sustainable development (Juntunen & Aksela, 2014) or tattoo colours (Stuckey & Eilks, 2014).

There are only few articles published that address the vocational relevance of chemistry teacher education. Early mentions have been made by Childs (2002) who reported a case study of different development actions made in the Irish chemistry education during 1999–2002. Childs

described structures and processes that were developed for promoting career awareness in chemistry and physics but also in their teaching profession. Hugerat et al. (2015) argue that the vocational dimension is often neglected in pre-service chemistry teacher training. They propose that it can be strengthened by teaching future chemistry teachers in a similar way that they are taught to teach their future pupils – i.e. through inquiry-based collaborative learning in a highly relevant context.

The vocational possibilities of non-formal learning for chemistry teacher education is the most studied topic under this theme (Affeldt et al., 2015, 2017; Aksela, 2017; Garner et al., 2014, 2015; Garner & Eilks, 2015). These studies are carried out in non-formal chemistry laboratories located in universities or chemical industry (Tolppanen et al., 2015). According to these studies, non-formal learning offers two great possibilities. The first one is promoting in-service teachers' continuous professional development through learning in non-formal chemistry laboratories during study visits (e.g. Affeldt et al., 2017). The second one is using a non-formal chemistry laboratory as a learning environment in undergraduate chemistry education courses which seem to offer many possibilities for learning and developing teacher identity. Aksela (2017) studied pre-service chemistry teachers' perceptions of relevance when they engage in guiding study visits in a non-formal chemistry laboratory. According to her case study, analysed from the vocational perspective, it strengthened their knowledge of chemistry and PCK. In addition, it confirmed the right career selection and increased self-confidence.

METHODS

This research was carried out as a case study utilising a mixed methods approach (Cohen et al., 2007). Data was gathered via an online questionnaire between January 2017 and December 2019 in the end of every chemistry education course held in the Unit of Chemistry Teacher Education at the Department of Chemistry in the University of Helsinki, Finland. The unit organises eight courses every year. All learning methods (see Table 2) included in the courses are selected through latest CER recommendations and these are aligned with the objectives set by the Finnish curriculum. (see Aksela, 2010)

All together 72 future chemistry teachers participated in the research. 34 respondents were studying chemistry as their 1st teaching subject, 36 as their 2nd teaching subject and two respondents left teaching subjects unanswered.

The questionnaire included 14 items divided into five sections (1. Background information, 2. Writing, oral and lab exercises, 3. Teaching and presentations, 4. Chemistry education research and 5. Other feedback). For ensuring a mixed methods approach, the questionnaire included both closed and open items. Closed items were five-point Likert-scales (1 completely meaningless – 2 somewhat meaningless – 3 neutral option – 4 somewhat meaningful – 5 very meaningful) and they were used for gathering students' perceptions of the relevance of different learning methods (see full list from Table 2). Every closed item was followed by two open items where respondents were asked to write justifications for the most relevant and irrelevant methods.

The most relevant and irrelevant methods (RQ1) were analysed via descriptive statistics including frequency distributions, means and standard deviations. Statistical phase was used for identifying the most relevant and irrelevant methods. Data from open items triangulated statistical results. They were used for understanding the reasons why future chemistry teachers experience some methods more relevant or irrelevant than others (RQ2).

RESULTS

Future chemistry teachers experienced that laboratory related methods *(M_{design} = 4.6, SD = 0.65; $M_{inquiry\text{-}based}$ = 4.3, SD = 0.68; M_{short} = 4.2, SD = 0.84)*, teaching sessions for peers *(M = 4.5, SD = 0.62)*, working in a non-formal learning environment with real pupils *($M_{guiding}$ = 4.4, SD = 0.89; $M_{observing}$ = 4.3, SD = 0.78)*, discussions *(M = 4.4, SD = 0.71)* and group work exercises *(M = 4.3, SD = 0.83)* were highly relevant from the vocational perspective. Also, traditional chemistry exercises (e.g. calculations and reaction mechanisms) *(M = 4.3, SD = 1.00)* and lectures *(M = 4.2, SD = 0.76)* were reported important. Writing assignments like learning diaries *(M = 3.5, SD = 1.05)*, summaries and short texts *(M = 3.6, SD = 0.96)* and drama activities *(M = 3.5, SD = 0.90)* were experienced less relevant than hands on activities or teaching exercises. Writing a blog text about personal learning was experienced irrelevant *(M = 2.5, SD = 0.81)* (see Table 2).

Table 2. Learning methods organised from relevant to irrelevant.

Learning activity	Activity Category	1	2	3	4	5	Mean	Std. Deviation	N	Response rate
Designing laboratory activities	Laboratory	0	0	6	15	47	4.6	0.65	68	94%
Peer teaching session	Teaching	0	1	1	24	36	4.5	0.62	62	86%
Discussions	Collaboration	0	2	3	28	37	4.4	0.71	70	97%
Guiding a study visit in a non-formal chemistry laboratory	Teaching	1	1	6	15	33	4.4	0.89	56	78%
Group work	Collaboration	1	3	1	32	33	4.3	0.83	70	97%
Observing a study visit in a non-formal chemistry lab	Teaching	0	2	1	18	16	4.3	0.78	37	51%
Inquiry-based open laboratory activities	Laboratory	0	1	5	33	25	4.3	0.68	64	89%
Chemistry exercises	Exercise and lecture	1	2	0	13	15	4.3	1.00	31	43%
Lectures	Exercise and lecture	0	2	8	33	26	4.2	0.76	69	96%
Shorter closed laboratory activities	Laboratory	0	3	5	23	21	4.2	0.84	52	72%
Peer evaluation	Evaluation	0	1	6	39	19	4.2	0.65	65	90%
Project working	Collaboration	1	2	7	36	20	4.1	0.82	66	92%
Textbook content analysis	Chemistry education research	0	1	4	15	8	4.1	0.77	28	39%
Design-based research	Chemistry education research	0	4	5	15	13	4.0	0.97	37	51%
Short oral presentation	Teaching	1	1	12	28	14	3.9	0.84	56	78%

School visit	Teaching	0	5	9	19	16	3.9	0.97	49	68%
Scientific essay	Chemistry education research	0	6	8	24	16	3.9	0.95	54	75%
Research group visit	Exercise and lecture	0	4	7	17	11	3.9	0.94	39	54%
Research report	Chemistry education research	1	1	8	16	9	3.9	0.93	35	49%
CER data gathering via questionnaire	Chemistry education research	2	1	5	13	9	3.9	1.11	30	42%
Case study	Chemistry education research	1	4	7	15	10	3.8	1.06	37	51%
Summary or short text	Writing	1	5	9	21	6	3.6	0.96	42	58%
Learning diary	Writing	2	9	9	26	7	3.5	1.05	53	74%
Roleplay and drama exercises	Exercise and lecture	0	7	11	19	4	3.5	0.90	41	57%
Blog texts	Writing	1	12	5	3	0	2.5	0.81	21	29%

Justifications for vocationally relevant learning methods

Laboratory work was seen as vital in chemistry teacher education. An exercise where students designed new laboratory activities was experienced especially relevant. Respondents felt that this kind of expertise has a major role in chemistry teacher's daily work. It also enables thinking about pupils' learning needs and supports their own learning.

- *"Designing new laboratory activities has a major role in chemistry teacher's work. Even the new curriculum guides into this direction."* (R6)
- *"Designing laboratory activities enabled studying the content more carefully."* (R23)
- *"Designing laboratory activities enabled thinking about what pupils should think*." (R24)

On the other hand, e.g. open inquiry-based laboratory activities were experienced difficult if the results are not clear. In addition, the relevance of laboratory work can be supported through interesting contexts.

- *"Inquiry-based laboratory activities don't always provide meaningful results."* (R1)
- *"Laboratory work was a bit like a separate section. It could have been integrated inside some other theme."* (R48)

All learning methods that increase teaching experience were experienced highly relevant. For example, teaching example lessons for peers helped learning content knowledge and getting familiar with teaching material development. Working in a non-formal chemistry laboratory with real pupils gave teaching experience and strengthened self-confidence.

- *"When we prepared the peer teaching session, we had to think about what is important for future chemistry teachers."* (R11)
- *"While we prepared materials for the peer teaching session, we had to learn the content profoundly and analyse our presentation critically."* (R13)
- *"Guiding a study visit for 7–9 grade pupils gave me experience on teaching chemistry through laboratory work. I found it useful."* (R54)

- *"Working in a non-formal learning environment helped me to understand what it is like to work with pupils. Experience of real teacher work."* (R51)

Future chemistry teachers experienced learning discussions (e.g. online/face-to-face discussions in pairs, small groups or within the whole class) as one of the most relevant learning methods. They felt that sharing own ideas, and hearing each other's thoughts forced to think and argument. Collaboration with peers enabled creating new ways to see things. Online discussions were reported challenging if instruction was experienced unclear.

- *"Discussions, if they stayed on topic, forced to think and argument."* (R3)
- *"Discussions with peers expanded my thoughts about teacher's vocation."* (R10)
- *"In discussions, I got feedback from my own thoughts and heard different opinions. I feel that discussions expanded my thinking."* (R13)
- *"Online discussions were poorly instructed, and I didn't get much out of them."* (R39)

Justifications for vocationally irrelevant learning methods

Writing assignments were experienced vocationally most irrelevant. Some respondents felt that writing did not support learning, or they felt that writing is not done to support their own learning.

- *"I can't evaluate my learning through writing assignments."* (R50)
- *"I feel that learning diaries are totally useless. They only add stress."* (34)
- *"Sometimes reflections are written for the teacher not for yourself. That's why they are not meaningful for supporting learning. Even though writing is a good way to learn."* (R11)

Some students responded that an assignment is irrelevant because they already know how to write that particular text type (e.g. summaries). Some felt learning diaries and blog texts unclear or not suitable for supporting learning or teaching.

- *"I am already familiar with writing summaries."* (R2)
- *"Learning diary is an unclear idea."* (R32)
- *"I don't see any use for blogs in teaching or learning."* (R12)
- *"Blog writing is a personal way to express oneself so it should be optional."* (R4)

Drama exercises divided opinions. Some students found them relevant and others disliked them. Responses show that sometimes the perception of irrelevancy may result from the unclear assignment description.

- *"Roleplay and drama exercises are a waste of efficient study time. I understand that others like them and it seems that they have some pedagogical value. However, many times the content suffers because of the entertainment perspective. These favour people that like to entertain by their nature. Teachers need to learn how to present a lesson in a classroom. It is not acting.* (R9)
- *"Drama exercise taught me to explore my boundaries, so I don't think that it was meaningless."* (R21)

DISCUSSION AND CONCLUSIONS

The most relevant learning methods experienced by future chemistry teachers were different kinds of laboratory activities, teaching exercises and discussions. Writing exercises were seen less relevant than other types of learning methods. When analyzing the results, one must keep in mind that these are preliminary findings. This case study is a starting point for learning method discussion in pre-service chemistry teacher education.

From the laboratory activities, especially designing new laboratory work was seen relevant in multiple ways, e.g. laboratory working has an essential role in chemistry teacher's work or an efficient method for supporting own and pupils' learning. Future chemistry teachers experienced designing new activities more relevant than just performing them, which differs from upper secondary school students' perceptions. Upper secondary school students found performing laboratory activities more relevant than planning them (see Bolte et al., 2013).

All kind of collaboration with peers (e.g. teaching example lessons for peers and learning discussions) was also experienced highly relevant. Our findings concerning the possibilities of non-formal learning are consistent with earlier research. Aksela (2017) reported that working with study visits strengthened students' chemistry knowledge, CPK, self-confidence and career choice. Our results showed that both engaging in non-formal learning environment and teaching example lessons for peers have the same kind of effects.

It was interesting that writing exercises were experienced the least relevant. After all, writing is one of the most important ways to express thoughts, especially for academically trained experts. According to our data, it seemed that the problem was in many cases an unclear assignment description. Students felt that they had to write for the teacher, and that it didn't support their own learning. For future research, we suggest that it would be important to develop writing task models that would be experienced more relevant.

Analysing these results through Stuckey et al.'s (2013) model, the vocational relevance related to learning methods was mainly internal (skills and knowledge for career) and focused partly in the present learning needs and partly in the future career orientation. Extrinsic perspectives were not present in this data.

For ensuring the high vocational relevance in chemistry teacher education, we encourage chemistry teacher training programs to increase engaging with non-formal learning environments and all kinds of teaching exercises. Designing learning materials, preparing and holding lessons, evaluating learning effects and re-designing lessons in a collaborative learning setting is an efficient model for supporting future chemistry teachers' professional development. We agree with Hugerat et al. (2015) and Aksela (2010), who argue that students need to be taught using versatile methods. An active learner will become an active teacher. Good practices learned during university years will transfer into their teaching. Enthusiastic and proficient chemistry teachers will be the key solution for increasing the relevance of chemistry studies, and that is why developing chemistry teacher education into a more relevant direction is important.

ACKNOWLEDGEMENT

We would like to thank our SECO research group members for participating in the development of the online questionnaire and in data collection. Together we are more!

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