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Promoting teacher students' system competence by the development of interdisciplinary simulation games

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Abstract

To understand the complex relationships in a globalised world ongoing biology teachers need more than subject knowledge. In order to take part in the processes of sustainable development, they have to recognize those relations as a cross-linked system [1], [2]. Therefore an interdisciplinary promotion of system competence gets more and more importance. This competence is defined as the ability to understand, to describe and to model the organisation and the functions of a complex area of reality and to make predictions and regulatory measures for the exploitation and regulation of systems [3].
The practical course "INQUIRE for Students" is a teacher training program for ongoing biology teacher of the secondary level. It aims in the development of subject knowledge and methodological knowledge in respect to an Education for Sustainable Development (ESD) [4]. During the course the teacher students enlarge their system competence by investigating complex syndromes in the context of biodiversity loss and climate change e.g. the dramatically loss if the European lobster (Homarus gammarus) around the North Sea island Helgoland. They develop complex simulation games, conduct them with school classes and evaluate the impact of these games on the pupils´ system competence.
This qualitative meta-study evaluates the impact of the INQUIRE course on the teacher students´ professional development, their system competence and their Pedagogical Content Knowledge (PCK). Therefore, an interview study (pre-post-design) with 15 participants was conducted. The analysis followed the paradigm of the qualitative content analyses. The system competence was measured qualitatively and quantitatively with concept maps and syndrome nets.
The results demonstrate an increase of the students' subject knowledge and their PCK, especially the knowledge of instructional strategies for teaching science in the context of ESD. Furthermore, the students improved their ability to organize a system.

1. Importance and promotion of system competence

The system competence is considered as a key competence of the 21st century. Mehren et al. [5] define this competence as the ability to understand, to describe and to model the organisation and the functions of a complex area of reality (dimension 1) and to make predictions and regulatory measures for the exploitation and regulation of systems (dimension 2). Both dimensions consist of more subdimensions and can they be divided in three levels [6].
A distinctive system competence helps pupils to comprehend and structure the complex and cross-linked relationships in a globalised world. Therefore the promotion of this competence is an essential element of the Education of Sustainable Development (ESD) [2].
Different empirical studies document that the system competence can be trained with appropriate learning activities in socio-scientific contexts [7], [8], [9], [10]. Especially the work with the syndrome approach as well as the development and conduction of can help to promote the system competence [11], [12]. The learners' interest and the pre-knowledge as well as the teacher´s instruction influence the pupils' system competence [1]. Therefore ongoing teachers should be literate in system competence themselves and should have pedagogical knowledge how to promote this competence.

1.1 Syndrome approach

The syndrome approach, developed by the German Advisory Council on Global Change, is a tool to determine unsustainable developments and environmental problems in earth systems, by considering them as syndromes. Each syndrome of global change is based on a manageable number of cause-and-effect-interactions in the man-environment relationship, the so-called symptoms. To analyse the syndromes, the symptoms are connected in a cause-and-effect-diagram with reinforcing and extenuating relations. During the derivation of the syndrome step by step sustainable plans and

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arrangements for the syndrome regulation are developed [13]. The syndrome approach is an appropriate method to foster interdisciplinary thinking and acting of the learners [14].

2. The training program INQUIRE for Students

"INQUIRE for Students" is an academic practical course for ongoing biology and geography teachers. The course aims in the development of system competence, subject knowledge and methodological knowledge in respect to an Education for Sustainable Development (ESD) [4].
In the winter semester 2015/16 fifteen teacher students joined the INQUIRE course. The course was divided in three phases:
In the first phase the teacher students took part in a five-days-lasting field trip to Helgoland, an island in the German North Sea. Supported by a science educator and a geography educator the teacher students gained practical knowledge about inquiry-based science education (IBSE) and received information on the ecology, economics, politics and the history of Helgoland. The focus was set on the context of climate change and the loss of biodiversity in respect to species of the North Sea.
Since the 2nd World War the population of the European lobster (*Homarus gammarus*), the heraldic species of Helgoland, has dramatically decreased. To avoid the extinction of the lobster, the Alfred-Wegener-Institute founded a breeding station on Helgoland.
During the field trip to Helgoland the students analysed the local syndrome "Loss of the European lobster" by the connection of the elements of the system (e.g. effects of climate change, invasive species, effects of World War II, humans, tourism etc.), to elaborate the influences for the loss of the lobster population. In addition, they developed scenarios to avoid the extinction of this species.
In the second phase of the project the teacher students worked in two groups and applied the new information about the lobster syndrome to develop simulations games for 7th and 10th graders. The simulation games allowed the pupils to take over a predetermined role (e.g. ecologist, economists, tourism manager, and fisherman) and discuss, if the lobster breeding station of the Alfred-Wegener-Institute should be government-financed furthermore or not.
In the third phase the teacher students conducted these simulation games with the two school classes in the "Zoo am Meer" in Bremerhaven. During the simulation games the pupils acquired subject knowledge about the impact of climate change on ecosystem North Sea and the lobster population by conducting inquiry-based activities. At the end of the simulation game the pupils discussed and made a common-shared decision about the possible actions in respect to the lobster syndrome.
In addition, the teacher students developed a questionnaire to evaluate the impact of the simulation games on pupils´ learning outcome.

3. Research questions

The meta-evaluation of the INQUIRE courses focuses on the learning progress and professional development of the participating teachers students in respect to their system competence (SC), subject knowledge (SK) and pedagogical content knowledge (PCK).

4. Research design

The fifteen participating teacher students were asked for semi-structured partner interviews (duos) at the beginning and at the end of the INQUIRE course (pre-post-design). The interviews included open and closed questions as well as the joint development of concept-maps. In addition syndrome nets and teaching activities (simulation games) were resources of the meta-evaluation.
The recorded and transcribed interviews were analysed following the paradigm of the qualitative content analysis of Mayring [15]. The concept-maps were analysed based on their basic structure [16], range (all elements + relations) [9], structural index [17] and connection index [8].

5. Findings and discussion

5.1 Subject knowledge

The teacher students' subject knowledge increased noticeably. The questionnaire contains seven subject knowledge items related to the topics "Biodiversity", "Climate Change" and "Impacts of climate change on biological diversity" and a maximum score of 37 can be reached. All interview duos increased their subject knowledge. The average score increased from 11.1 (pre-test) to 18.6 (post-test).

5.2 System competence

The evaluation of the concept-maps (pre-test) demonstrated that only 50% of the participating teacher students used the complex “net structure”. One interview duo even used the “spoke structure”, which is considered as the structure with the lowest complexity [16].
In the post-test all interview duos developed complex concept-maps with the “net structure” and they were able to place twice as much elements and relations. The average range increased from 11.4 (pre-test) to 24.8 (post-test). But the teacher students could not increase significantly the average of connections between the elements, demonstrated by the connection index (Pre-VX= 2; Post-VX=2.1). The structural index showed that the complexity of the interconnections (forks, chains & loops) decreased from pre- to post-test (Pre-SX= 0.5; Post-SX=0.4). These results seem to confirm previous studies, which have revealed that it takes a certain time to foster the system competence [18]. Another problem is that the indices are calculated per element. So the huge increase of the placed elements disguises the smaller increase of complex interconnections.

5.3 Instructional strategies

The development of complex simulation games including IBSE elements had a positive influence on the teacher students’ knowledge of instructional strategies for teaching science. In the post-test the students knew twice as much strategies to foster pupils´ system competence as in the pre-test.
These results agree with the self-assessment of the teacher students. In the pre-test 75% of the participants estimated themselves as “Beginners” with regard to their knowledge of instructional strategies for teaching science in the ESD context. In the post-test 80% of the participants estimated themselves as “Advanced”.

6. Conclusions

The findings demonstrate that the work with the syndrome approach and the development of the complex simulation games had a positive influence on the teacher students´ subject knowledge and their knowledge of instructional strategies for teaching science. The analysis of the system competence shows that it takes a certain time to promote this competence significantly. It is therefore recommended to foster this competence during the teacher training interdisciplinary and over a long time.

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