Factors Influencing the Adoption of Systems Thinking in Primary and Secondary Schools in Switzerland

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Systems thinking is well suited to complement widespread linear thinking in schools. However, previous studies showed that computer modelling can act as a barrier. Therefore, this study focuses on qualitative systems thinking and thus excludes computers as potential barriers. We analyzed factors influencing the implementation of systems thinking in K-9 schools in Switzerland. In our design-based research teachers participated in a standardized training followed by several months of implementation in the classroom. The results showed that teachers’ ex ante knowledge of systems thinking was poor; however, this is not a barrier to integrate systems thinking in schools. Easy-to-access supporting material and motivational factors such as self-efficacy and self-determination proved to be important; however, above all, the attribution of significance by teachers is the most promising leverage to foster the adoption of systems thinking in classrooms. Although this may seem trivial, it offers new ways to disseminate systems thinking in schools. Copyright © 2015 John Wiley & Sons, Ltd.

Keywords systems thinking; implementation; attribution of significance; teaching; education policy

INTRODUCTION

The issue identified by LaVigne and her colleagues comes close to what this paper addresses. However, this study is not about the classroom implementation of system dynamics, that is, the quantitative modelling of systems by means of computer and software. A study by Skaza et al. (2013) showed that the use of computers seems

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to rather hinder the implementation of system concepts. Therefore, we focused on systems thinking in the sense of a ‘mental walk through’ (Richmond, 1994, p. 144). Systems thinking has many roots and branches and thus, several definitions exist (Ossimitz, 2000; Schwaninger, 2006). We do not refer to systems thinking in the understanding of, for instance, Checkland (1981), Checkland and Poulter (2007), Beer (1979, 1984), Espejo (1994), Rosenhead (1980) or Rosenhead and Mingers (2001). In this study, we understand systems thinking in the sense of structural thinking (Richmond, 1994) accompanied by qualitative system dynamics diagrams (Lane, 2000). This includes the qualitative application of system dynamics concepts (e.g. structure of a system, stock and flow, causal links, feedback loops, linear and non-linear changes and delays) and tools (e.g. connection circle, causal loop diagram and behaviour over time graphs) by concurrently addressing the habits of a systems thinker (e.g. big picture, change of perspectives, interdependencies and change over time) (Waters Foundation, 2015). We acknowledge that the use of systems thinking in the sense of qualitative system dynamics modelling as described before reduces the potential impact of quantitative system dynamics (Forrester, 1994; Richmond, 1994; Lane, 2000). However, if we want to investigate factors limiting the adoption of the underlying structural thinking of system dynamics apart from the still impedimental issues of computer and software, this is one way we propose to go.

Systems thinking is considered as a beneficial approach to complement widespread linear thinking. Although ideas of systems thinking (but not quantitative system dynamics) are to be found amongst the guiding principles of many K-12 curricula throughout the world, also in Switzerland, neither systems thinking nor system dynamics and their concepts and tools are mentioned explicitly in the content of the educational standards themselves (Deutschschweizer Erziehungsdirektoren-Konferenz (D-EDK), 2014), be it primary, secondary or tertiary education. In the USA, however, the educational value of systems thinking has been recognized by the authors of the framework for K-12 Science Education. Concepts such as cause and effect, flows, feedback loops, behaviour patterns as well as systems and system models themselves (however not quantitative modelling) are part of this framework (National Research Council, 2012, p. 84). Furthermore, one can find ideas and concepts of systems thinking embedded within the Common Core State Standards of subjects like mathematics, English language arts and social studies (NGA Center & CCSSO, 2010).¹

Experiences demonstrate that the basic concepts and tools of systems thinking can be taught from kindergarten up to tertiary education (Ossimitz, 2000; Stuntz and Lyneis, 2007; Frischknecht-Tobler et al., 2008). There is teaching material available to support teachers of all grades (e.g. Creative Learning Exchange; Waters Foundation; Quaden et al., 2007a, 2007b; Bollmann-Zuberbühler et al., 2010). Yet the question remains: why does systems thinking, not to mention system dynamics, not find its way into classrooms on a broader scale (Fisher, 2011)? Or in the words of Stuntz and Lyneis (2007): ‘Unfortunately, most of the [intervention] programs described … have not been able to maintain initial momentum after major outside funding ended. Why is that?’ Our objective is to enhance the understanding of the factors leading to acceptance of systems thinking in educational institutions and addresses the following research question: what factors — barriers as well as enablers — influence the willingness of teachers to adopt and implement systems thinking?

FACTORS INFLUENCING THE ADOPTION OF SYSTEMS THINKING IN SCHOOLS

If systems thinking — as a stepping stone for full-fledged system dynamics — should be disseminated in schools, we need to learn more about factors that influence its adoption. Until now, not many studies have been conducted with this perspective. The most recent study by Skaza et al. (2013) found that the use of computers does hinder the implementation of system concepts because of the additional knowledge requirements of using simulation software. Richmond’s
situational impediment number one, even though brought forward in 1991, seems still to be valid: ‘Although advances in technology are making technical impediments less of an issue, for some people, technology itself is frightening, de-humanizing, or otherwise dastardly’ (Richmond, 1991). Ossimitz (2000) found in his study with 126 students aged 15–19 from seven different classes that working with simulation software did not foster systems thinking more than working systematically with causal-loop diagrams and behaviour-over-time graphs. Obviously, approaching schools with systems thinking without computer-based modelling seems to be a promising first step to promote the basic idea of system dynamics. By excluding this known barrier, we want to disclose the obstacles, other than ICT-related factors, for teachers not to include systems concepts in teaching on the primary and secondary school level.

In the USA, Stuntz and Lyneis (2007) have reflected on strategies for a wider adoption of system dynamics by teachers and schools. Fisher (2011) offered an overview of consecutive system dynamics strategies for K-12 institutions that have been successfully taught for many years (Fisher, 2011). Nevertheless, particularly in Switzerland where this study has been conducted, systems thinking and system dynamics can still be considered as novelties in the educational field in the sense of ‘an idea, practice, or object that is perceived as new by an individual or other unit of adoption’ (Rogers, 2003, p.12). Therefore, we reviewed the literature about the transfer of innovations with a special focus on transfer of innovations into educational institutions (Guskey, 1988; Gräsel, 2010; Bourrie et al., 2014) and above all we looked into research about the transfer of innovations similar to systems thinking like, of course, system dynamics (Fisher, 1998; Lyneis, 2000; Lyneis and Fox-Melanson, 2001; Stuntz and Lyneis, 2007; Skaza et al., 2013) and education for sustainable development (Schellenbach-Zell and Gräsel, 2010; Trempler et al., 2012). As recurring pattern from our review, the factors and characteristics of the transfer of innovation can be summarized into three clusters: (1) the characteristics of the individual school, its work environment and its support structure; (2) the characteristics of the teachers involved, including their motivation and approach towards teaching; (3) the factors of the innovation itself, in our case the subjectively received usefulness and availability of teaching and training material. In the following, we summarize for each of these three clusters those factors that influence the transfer of innovation according to literature findings the most.

Institutional Factors of Schools

Because a change on the institutional level depends on an innovative climate, the attitude towards the innovation of administrators and how innovative teachers perceive their school seems to be a significant factor (Bourrie et al., 2014). This has been confirmed in studies about the implementation of system dynamics (Lyneis, 2000; Stuntz et al., 2002). The climate of innovation of a school is also expressed in incentives such as time and funding provided, but also in social recognition by the principal, the board and colleagues (Guskey, 1988; Schellenbach-Zell and Gräsel, 2010; Bourrie et al., 2014).

Individual Factors of Teachers

According to findings in literature, the following motivational factors seem to influence the adoption of innovations: The attribution of personal significance, that is, the importance a person attaches subjectively to the object in question (Krapp, 1999), has been identified by Schellenbach-Zell and Gräsel (2010) as a particularly important factor in a project where the innovation was about education of sustainable development, a topic closely related to systems thinking. Teachers’ self-efficacy beliefs, that is, ‘belief in one’s own capability to organize and execute the courses of action required to manage prospective actions’ (Bandura, 1997) are consistently identified as being of importance for implementing new ideas in the classroom (Guskey, 1988; Schellenbach-Zell and Gräsel, 2010; Bourrie et al., 2014). In the context of our study, this means that it is important that
teachers believe that they are capable to work with the concepts, tools and habits of systems thinking they were shown in the training. As a further personal factor, Schellenbach-Zell (2009) pointed out that procrastination, that is, ‘to voluntarily delay an intended course of action despite expecting to be worse off for the delay’ (Steel, 2007) hinders the adoption of an educational innovation. And last but not least the three factors of self-determination, that is, the experience of autonomy, competence and relatedness (Deci and Ryan, 1985) seem to play an important role when beginning to use new approaches to teaching (Schellenbach-Zell and Gräsel, 2010).

A final factor regarding teachers is the innovativeness of the individual (Bourrie et al., 2014). Research has shown that a small group of early adopters can effectively stimulate the adoption of an innovation within their community (Rogers, 2003), whereas others do resist if they do not see a need for change or how the innovation can be implemented in practice (Terhart, 2013, p. 488).

Factors of the Innovation Itself: Material for Teaching and Training

Finally, there are characteristics of the innovation itself that influence its implementation. Amongst others, the ease of use, the practicality of the innovation as well as the relative personal advantage are consistently named as important factors (Guskey, 1988; Gräsel, 2010; Bourrie et al., 2014). In order to facilitate the ease of use and the practicality, it is important to support the process of adoption with project-specific material, that is, teaching resources, lesson plans and textbooks that can be used without much extra effort. Furthermore, Stuntz and Lyneis (2007) pointed out that the provided teaching material needs to be well integrated into existing curricula. And last but not least, the professional development and training that is provided to introduce the innovation has a strong impact on what happens afterwards in the classroom. The training therefore needs to be standardized, so that all participants of this study have the same preconditions.

RESEARCH METHOD

Context

We conducted our research in classes K-9 in the German speaking part of Switzerland, which is the compulsory education equivalent to a combined elementary and lower level secondary education in the USA. Our study differs from existing work in that it, first, focuses on a broad range of classes, from kindergarten (age 5–6) up to year 9 (age 15). Second, this study includes school teachers from urban as well as rural environments and thereby obtains a diverse sample for analysis. Third, teachers were not restricted to apply systems thinking to a specific subject so that teachers’ deficits of understanding about a given subject matter do not bias the acceptance of systems thinking.

Research Design and Data Collection

As our research questions aimed at both the adoption as well as implementation of systems thinking in the classroom, we applied a design-based research approach (The Design-Based Research Collective, 2003; Krüger et al., 2014, Chapter 3) composed of a pre-post design to evaluate factors potentially influencing the adoption of systems thinking, supplemented by action research to assess the implementation of systems thinking and the development of the teaching material.

We used multiple methods to collect data (Figure 1) consisting of, first, a survey at the day of the standardized training session (in order to keep questionnaires short, the pre-assessment was split into two questionnaires, t1 immediately before the training and t2 immediately after the training); second, a post-survey after the participants finished their implementation of systems thinking in the class and third, an individual in-depth interview after the second survey. As the response rates at the three different points of assessment varied significantly, the data has been analyzed case-wise for each variable.
Training

The participants were offered a 1-day standardized training. During the training, teachers were familiarized with the concepts, tools and habits of systems thinking (Table 1). Participants were given practical examples how systems thinking could be integrated in their teaching. Amongst specific ideas about how to link systems thinking with the existing curriculum, teachers experienced the following playful systems thinker activities (Table 1). A textbook (Bollmann-Zuberbühler et al., 2010) was provided as supporting material containing a number of cross-curricular systems training units and activities for all grades and ages but without subject-specific lesson.

Survey

Based on the review of the literature, we focused our written questionnaires on the three main clusters of factors: institutional factors of schools, individual factors of teachers and teaching material. The questionnaires consisted of mainly closed-ended items that had to be answered on a four-level Likert scale. The questions were based on the pre-existing scales of other studies. For some items, we adapted the wording to match our purposes. Appendix A shows a summary of the used scales including the values of the Cronbach’s alphas as well as the original source of the items and corresponding example items. With values all above 0.73, the Cronbach’s alphas demonstrate satisfying internal consistencies for all scales used in the surveys (Table A.1).

Table 1 Concepts, tools, habits and activities addressed in the systems thinking training

<table>
<thead>
<tr>
<th>Concepts</th>
<th>Tools</th>
<th>Habits</th>
<th>Activities</th>
</tr>
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<tbody>
<tr>
<td>Describing the structure of a system: system, systems elements, systems boundaries;</td>
<td>For linear connections: chain of connection;</td>
<td>The adoption of systems thinking includes the change of habits and individual behaviour (Meadows, 2008, p. 164). In our training, we addressed eight out of the 13 habits of a systems thinker promoted by the Waters Foundation (2015).</td>
<td>Arms crossed, Avalanche, Circles in the Air, Frames, Web of life (Booth Sweeney and Meadows, 2010)</td>
</tr>
<tr>
<td>Identifying connections between systems elements: causal links, cycles, feedback loops;</td>
<td>For interconnections: connection circle, causal loop diagram;</td>
<td></td>
<td>The Connection Game and its variations (Quaden et al., 2007a; Bollmann-Zuberbühler et al., 2010)</td>
</tr>
<tr>
<td>Verifying systems dynamics: change over time, linear and non-linear changes, delays;</td>
<td>For aspects of dynamics: table of values, behaviour over time graphs;</td>
<td></td>
<td>Dancing Polonaise, End of the world, Feedback Games, Knit a net, Fishpond, Storytelling, (Bollmann-Zuberbühler et al., 2010)</td>
</tr>
</tbody>
</table>
The following open question has been used to assess teachers’ pre-conceptions of systems thinking: ‘Explain your understanding of systems thinking to a colleague of yours.’ The answers to this open question have been categorized from ‘1’ (naive or very limited conceptions) to ‘5’ (very sophisticated conceptions).

**Participants**

The teachers have been recruited in two ways: 92 teachers took part in a mandatory school-internal training about systems thinking. Fifty-one teachers enrolled voluntarily in a professional training course on systems thinking of exactly the same format. This approach allowed for a comparison between voluntary participants (group ‘Voluntary’) and the attendants of the mandatory professional development (group ‘Mandatory’). Furthermore, we made a distinction between teachers who implemented only a few isolated exercises on systems thinking in their classes (group ‘Low Implementers’) and those who implemented several lessons during a significant number of weeks (group ‘High Implementers’). These last two groups were studied to analyze differences between low and high implementers. In addition, 32 participants provided protocols with further information about what happened in the classrooms.

Our sample consisted of 143 teachers (28% male). Seven per cent of the participants taught in kindergarten (0% male), 54% in primary schools (11% male), and 41% in secondary schools (17% male).

**RESULTS**

From the sample of 143 participants, 60 teachers (42%) integrated at least some systems thinking activities in their classroom. Participants who attended the professional training voluntarily (N = 20) showed a higher rate of implementation than mandatory participants of the training (N = 40) (ANOVA, df = 1/66, F = 5.196, p < 0.05; Figure 2).

The group of implementing teachers could be divided into a group that conducted only little to a few single systems thinking activities (36.67% ‘Low Implementers’) and a group of teachers that implemented parts of or an entire systems training during several lessons or during several weeks (56.67% ‘High Implementers’). In 6.67% of the cases, the amount of implementation could not be determined. From the group ‘Voluntary’, more than 60% of those who implemented systems thinking belonged to the ‘High Implementers’, whereas from the group ‘Mandatory’, not even 45% of the implementing teachers could be assigned to the ‘High Implementers’.

![Figure 2 Degree of implementation grouped by mandatory vs. voluntary participation](image-url)
Thus, before taking a closer look at characteristics that distinguish ‘High Implementers’ from ‘Low Implementers’, differences between the groups of ‘Voluntary’ and ‘Mandatory’ are analyzed.

Comparison Between ‘Voluntary’ and ‘Mandatory’ (Appendix B, Table B.1)

The results of the categorization of the open question about teachers’ pre-conceptions of systems thinking revealed that ex ante knowledge of systems and of systems thinking were poor in both of the groups ‘Voluntary’ (V) and ‘Mandatory’ (M). Even though teachers who participated voluntarily showed significantly higher scores than teachers who participated mandatorily (MV = 1.96 vs MM = 1.67, p < 0.01), the absolute value of ex ante knowledge can be considered as rather low as ‘5’ is the highest rating that could be achieved. The general poor ex ante knowledge does not come as a surprise as it is consistent with existing findings (e.g. Booth Sweeney and Sterman, 2007; Skaza et al., 2013).

The results of the closed-ended questions with a range from ‘1’ (minimum) to ‘4’ (maximum) showed the following pattern: when looking at the institutional factors of schools, there is no significant difference between how the two groups judge the incentives offered by their respective schools. With means below ‘2’ out of a maximum of ‘4’, the teachers do not seem to need much incentive. The attitude of the schools towards innovation, however, seems to differ between these groups: the group ‘Voluntary’ feels that their schools do not care as much about an innovative environment as do schools of the group ‘Mandatory’ (MV = 2.59 vs MM = 3.02; p < 0.001). Regarding the individual factors of teachers (Appendix B, Table 3, middle), the results show the following differences between the two groups: the teachers of the group ‘Voluntary’ attributed more significance to systems thinking than the teachers of the group ‘Mandatory’ (MV = 3.61 vs MM = 3.25; p < 0.001). Within the three dimensions of self-determination, the two groups differed only in the experienced autonomy with the group ‘Voluntary’ rating higher (MV = 3.69 vs MM = 3.04; p < 0.001). When it comes to procrastination or self-efficacy, we could not find differences between the two groups. The latter shows with reasonably high values of (MV = 3.6 vs MM = 3.33; ns) that both groups seemed to feel quite confident after the one day training session to include systems thinking in their teaching. Concerning the teaching material (Appendix B, Table 3, bottom), both groups coincided that there should be more teaching material available (MV = 2.02 vs MM = 2.35; ns); however, the ‘Voluntary’ considered the textbook significantly better suited than the ‘Mandatory’ (MV = 3.08 vs MM = 2.37; p < 0.001).

Comparison Between High and Low Implementers (Appendix B, Table B.2)

Regarding the institutional factors of schools, the high and low implementers do not differ significantly. Nevertheless, the ‘High Implementers’ (H) considered their schools as slightly less innovative than the ‘Low Implementers’ (L). The means close to ‘3’ out of ‘4’ of the scale ‘innovative working environment’ imply that the attitude of the schools towards innovation may be of importance for the adoption of systems thinking in schools (M_L = 2.98 vs M_H = 2.87; ns). With values around ‘2’ (out of ‘4’), neither group seemed to require much incentives for the implementation of systems thinking

When it comes to individual factors of teachers, there are significant differences between the two groups. Teachers who dedicate more teaching and didactic work (MV = 3.61 vs MM = 3.25; p < 0.001), more competence (ML = 2.65 vs MH = 3.28; p < 0.01), slightly more relatedness (ML = 2.72 vs MH = 2.83; ns) and they do not procrastinate (ML = 2.62 vs MH = 1.99; p < 0.001) as much as their colleagues who have only implemented single activities of systems thinking. However, they do not feel more confident teaching it (self-efficacy: ML = 3.26 vs MH = 3.34; ns). The two groups differ significantly when it comes to the attribution of significance. ‘High Implementers’ rate systems thinking much more relevant than ‘Low Implementers’ do (ML = 2.93 vs MH = 3.37; p < 0.01). When looked at the absolute values of the
various variables, self-efficacy, the experience of autonomy and competence and the attribution of significance are rated with values above ‘3’ out of ‘4’ and therefore appear to be important factors to foster implementation. Neither the suitability nor the availability of teaching material made a difference between the two groups. With the values of the means of the availability of material lower than ‘2.5’ and with values of the suitability of the textbook below ‘3’, both variables could be higher but seemed not to be major obstacles.

DISCUSSION

The Role of Schools

Participants of the group ‘Voluntary’ do neither consider the environment at their schools as very supportive for their work with systems thinking nor do they see much incentive for doing so. Therefore, the influence of the ‘Voluntary’ in fostering systems thinking at their schools seems to be limited. This leads to address entire schools instead. Our study, which included the teaching staff of entire schools, showed no significant difference between high and low implementers regarding the rating of the attitude of schools towards innovation. But the high average value of the scale ‘innovative working environment’ suggests that this factor influences the adoption of systems thinking in schools. This is supported by interviews that revealed a lack of common vision and clear goals in some schools, whereas in other schools, a systemic approach towards innovation seemed to help the implementation of systems thinking.

«Yes, it was mandatory, but of course there are always exceptions. [laughs]» [secondary school teacher, mandatory participant, no implementation]

«We have this task to implement something new once a year.» [secondary school teacher, mandatory participant, high implementation]

Surprisingly, the low values of the variables concerning incentives indicated that teachers did not require much external stimulation for the implementation of systems thinking. This contrasts partially with the findings of Schellenbach-Zell and Gräsel (2010) and with statements from the interviews of our study.

«And the principal visited the presentation, gave me feedback and this was very interesting for me.»
[secondary school teacher (social sciences), mandatory participant, high implementation]

Valuing the efforts of the teachers, visiting lessons and providing feedback seem to play a certain role although they do not significantly show up in the quantitative data. Optimizing materials, forming teams for collaboration and exchange of ideas are further distinguishing factors mentioned by teachers of schools where the implementation of systems thinking as part of school development was more successful and should therefore be considered when approaching schools with innovations in general and with systems thinking in particular.

The Role of Teachers

As Gräsel (2010) points out the importance of early adopters for the diffusion of innovation, one of our strategies to disseminate systems thinking in schools consisted in recruiting voluntary participants who we considered to be early adopters, that is, people who accept an innovation because they see a benefit in it and have the highest degree of opinion leadership (Rogers, 2003). These highly motivated teachers would activate their colleagues and help to spread systems thinking. According to our findings, however, the implementing voluntary participants remained isolated individuals in their schools. Thus, they were no strong leverage to spread systems thinking in schools. A closer look at the data and the interviews showed that what we considered as early adopters were in reality ‘lonely wolves’, that is, teachers who experienced a high sense of autonomy but who had not necessarily the highest degree of opinion leadership.

So, if it is not the highly self-motivated voluntary participant that could be used as a leverage to foster systems thinking in schools, what are focal points to consider that are independent of voluntary or mandatory participation in the
training? Teachers who are willing to implement systems thinking in the classroom can be characterized as follows: they feel competent and experience much autonomy when teaching systems thinking (self-determination), they do not procrastinate, they consider it important to address social responsibilities in their classroom and they see systems thinking as relevant. However, in contrast to previous studies (Guskey, 1988; Schellenbach-Zell and Gräsel, 2010; Bourrie et al., 2014) we found no significant difference in the self-efficacy beliefs between high and low implementers. A possible explanation lies in the fact that we used a scale of general teaching self-efficacy (Halbheer et al., 2005) instead of items that were specific for systems thinking as Schellenbach-Zell and Gräsel (2010) did in their work.

Nevertheless, the question remains: which of the differentiating factors may be a good leverage to foster systems thinking in schools? Schellenbach-Zell (2009) supports the impact of procrastination, and also, the importance of self-determination is found to influence the adoption of educational innovations in previous studies (Schellenbach-Zell and Gräsel (2010). However, if we are looking for factors that could act as leverage, neither procrastination nor the elements of self-determination can easily be addressed directly. This leaves the attribution of significance, which in our study and in strong accordance with Schellenbach-Zell and Gräsel (2010), turned out to be crucial. This is also in line with Skaza et al. (2013) who identified teachers’ beliefs as an important internal barrier to the adoption of system dynamics apart from the use of technologies and software.

The Role of Training, Teaching Material, Standards and Curricula

Although ‘Low Implementers’ did not feel a significantly higher need for more systems thinking-specific teaching material than ‘High Implementers’, and although both groups rate this demand quite low (<2.5), this expresses a need that could not be fulfilled optimally. Even in the English-speaking countries where there are excellent textbooks available that provide easy ways to introduce general concepts of systems thinking (e.g. Quaden et al., 2007a, 2007b), this does not necessarily respond to the call of Stuntz and Lyneis (2007) for material that is well-integrated into the curricula of individual subjects. Our findings clearly support the claim of Stuntz and Lyneis (2007) for sequential curriculum materials not only at all levels but above all related to specific topics that are explicitly listed in the educational standards.

One day of training proved to be sufficient only for the ‘High Implementers’, although all teachers had access to the textbook that included electronic teaching material specific for systems thinking. It also turned out that those teachers who asked for coaching during implementation all belonged to the group of ‘High Implementers’. It seems that teachers who recognized the significance of systems thinking were able to benefit from the limited duration of the training, saw ways to link systems thinking with the curriculum and asked for support. To address the needs of all teachers, the training has to be designed along the lines that Lyneis (2000) show that an introductory training should be followed by teachers working in teams on the implementation coached by the trainers and experts who visit and give feedback to the teams in their classrooms.

Summary of the Most Influential Factors

Although our data do not allow statistical path analysis, we can nevertheless take a systemic view and hypothesize the following causal loop diagram (Figure 3). Based on our results, we included only those variables in our model that either significantly differentiated between high and low implementers or were rated higher than M = 3.0 (Appendix B, Table 4) or were mentioned repeatedly in the interviews.

Once people consider systems thinking as important, they feel competent enough to work with systems thinking concepts, tools and habits in the classroom; they explore ways to connect systems thinking autonomously with the curriculum. In addition, they use and develop material
for the implementation of systems thinking, even if the initial understanding of systems thinking is poor. Our analysis can be summarized in three feedback loops that help to reinforce such a development: high-quality teaching material available helps teachers to experience systems thinking competence and thus lowers the barrier to use available material for integrating systems thinking into their teaching (R1). The more teachers are able to link systems thinking to the given curriculum and educational standards, the more they recognize systems thinking as significant, which strengthens their self-efficacy and consequently their experience of competence that leads again to a more autonomous approach to the curriculum (R2). And finally, the availability of quality material also helps to intensify teachers’ attribution of significance to systems thinking, which increases their self-efficacy and experience of competence which in return facilitates the use of available teaching material (R3).

According to our model (Figure 3), teaching material and the connection to the curriculum influence the implementation of systems thinking at a respective institution directly, whereas the attribution of significance exerts its influence indirectly by way of fostering teacher’s experience of competence. As the systems thinking and system dynamics communities have little impact on the curriculum standards of a state or a country, this leaves the availability of teaching material and the strengthening of the perceived significance to foster systems thinking and system dynamics in schools. Therefore, before addressing concepts and tools of systems thinking, it is important to convince a majority of teachers of a school of the significance of systems thinking. This can be achieved with ‘appetizer sessions’ of 1 to 3h in length that showcase exemplarily some applications of systems thinking (and system dynamics) in everyday life and in schools and how to connect it with the requirements of the curriculum and standards. However, if we look at experiences made with the implementation of system dynamics, this will not be sufficient, or as Fisher states, it is a mistake «thinking that showing teachers system dynamics models and how they are useful is enough to get them to use them in class.» (Fisher, 1998). Thus, once the audience recognizes the power of this approach, it is important to follow up relatively soon with workshops where the concepts, tools and habits of systems thinking are thoroughly trained.

Figure 3 Causal loop diagram of how factors influence the likelihood of adopting systems thinking (ST) in the classroom

Variables currently not considered
- Attribution of significance of school board
- Principal’s attribution of significance
- Principal’s leadership
- School’s expectations of costs and benefits for teaching innovations

Variables currently considered
- Teacher’s experience of ST competence
- Teacher’s experience of autonomy regarding ST
- Teacher’s readiness to connect ST to curriculum
- Teacher’s proclivity
- Teacher’s self-efficacy
- Teacher’s attribution of significance to ST
- Availability of high quality teaching material on ST
- Likelihood to implement ST in the classroom

Innovative work environment
- Peer group dynamics
- Likelihood that colleagues implement ST in their classrooms
- Teacher’s attitude towards cooperation
- Teacher’s understanding of teaching and learning
- School’s computer facilties
- Teacher’s computer literacy
- Teacher’s attitude towards computers

Figure 3 Causal loop diagram of how factors influence the likelihood of adopting systems thinking (ST) in the classroom
Limitations of This Study

The rate of return of the last questionnaire (t3, Figure 1) in general and particularly from teachers who did not implement systems thinking at all (14 respondents) was too low to be included in the data analysis. In this way, we were limited in identifying the characteristics of non-implementers and had to restrict the analysis to a comparison between low and high implementers. As a consequence, the small sample size did not allow for more sophisticated statistics. It would have been very interesting to apply a path analysis in order to quantify the impact of the various factors evaluated. As it is, we need to rely on our inferences on the descriptive results we got combined with insights gained from other studies.

Even though we were able to unearth three feedback loops, our model falls short accounting for other variables, which can be considered important when it comes to the implementation of systems thinking and system dynamics in schools and which are currently outside of our model boundary (Figure 3). In the interviews, the role of the principal as well as the board of schools has been mentioned several times. This is consistent with our observation that schools where the principal seemed to consider systems thinking as important had more high implementers than other schools. Therefore, it is important not only to look into teachers’ attribution of significance but also to research the beliefs of principals and members of the board. Probably connected with these factors are schools’ expectations of costs and benefits of teaching innovations. Other variables that have not been included in our model are teachers’ understanding of teaching and learning as well as the role of peer group dynamics, which may be influenced by the attitude of individual teachers towards cooperation but also by the leadership behaviour of the principal. And of course, all factors concerning teachers’ computer literacy and attitude towards computers and software are outside the boundary of our model. This intentional restriction to systems thinking without computer-based modelling may be considered a limitation of this study. Yet, our study provides answers regarding limiting factors other than computer and software of which the study of Skaza et al. (2013) has mentioned the understanding of system dynamics and the belief that system dynamics is not important in the classroom. The allocation of importance is in accordance with our findings. When it comes to getting teachers started with systems thinking, the knowledge of systems thinking, however, seemed to be less of a barrier than the felt sense of competency. Clearly, it is important that teachers comprehend the basic concepts and tools to avoid the building of misconceptions amongst their students. However, if teachers do avert systems thinking and system dynamics because they think this is too complicated, this does not help to promote the matter neither.

Finally, because the study has been carried out in the German-speaking area of Switzerland, this offers on the one hand additional potential to influence the dissemination of systems thinking in the German-speaking parts of the world. On the other hand, the organization of schools and in particular the incentives and resources for in-service teacher training seem to differ considerably from one country to another. Therefore, the recommendations for the implementation of systems thinking summarized in the following conclusion need to be adapted accordingly. However, as our results are strongly supported by previous findings from other countries, we consider it justified generalizing the following conclusions to a certain degree.

CONCLUSION

Why is systems thinking currently not diffusing in educational institutions and especially across schools? Based on our research, we derive four recommendations. (1) The most promising leverage of all factors we analyzed is to address the attribution of significance to systems thinking as this factor can be changed easier than the other relevant factors. (2) Although the highly motivated enthusiasts implement systems thinking in creative ways in their classroom, they are not the ones to promote it in their institutions. We recommend targeting entire schools and their
teams of teachers instead. (3) As a promising way to introduce systems thinking in a school, we propose the following approach: starting with a short session to have the participants understand and recognize the relevance of systems thinking; after this ‘appetizer’, a training needs to be offered with many subject-specific examples that can be linked directly to the curriculum followed by a phase of implementation of several months coached ideally by those highly motivated teachers mentioned in (2) who are already using systems thinking in their teaching; and finally, half a day of exchange of experiences and material. (4) Not only grade-specific teaching material and activities need to be available to the teachers, but also subject-specific resources with close references to the educational standards.

NOTE AND ACKNOWLEDGEMENTS

(1) For an overview of the connections between systems thinking to curricular standards see the Waters Foundation under http://waters-foundation.org/systems-thinking/standards/ or have a look at the brochure that can be downloaded from the website of the Creative Learning Exchange http://static.clexchange.org/ftp/CLEBrochure_2013.pdf.

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REFERENCES


Table A.1 Overview of statistics of applied item scales

<table>
<thead>
<tr>
<th>Scale</th>
<th>Number of items</th>
<th>α</th>
<th>M</th>
<th>SD</th>
<th>Source</th>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>10</td>
<td>0.867</td>
<td>2.85</td>
<td>0.564</td>
<td>Halbheer et al. (2005)</td>
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<td>11</td>
<td>0.897</td>
<td>2.04</td>
<td>0.647</td>
<td>Schellenbach-Zell (2009)</td>
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<td>1.91</td>
<td>0.767</td>
<td></td>
</tr>
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<td>1.74</td>
<td>0.775</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-efficacy (t2)</td>
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<td>3.30</td>
<td>0.378</td>
<td>Halbheer et al. (2005)</td>
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<td>3.06</td>
<td>0.603</td>
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<td>0.66</td>
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<tr>
<td>Attribution of significance (t2)</td>
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<td>3.36</td>
<td>0.47</td>
<td>Schellenbach-Zell (2009)</td>
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<tr>
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<td>Beck et al. (2008)</td>
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<td>Teaching material</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>2.84</td>
<td>0.685</td>
<td>Adapted after Wirthensohn (2012)</td>
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<tr>
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<td>0.847</td>
<td>2.26</td>
<td>0.744</td>
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</tr>
</tbody>
</table>

Sources of scales


Example items

The following short descriptions of the various scales with sample items give an impression of the sort of questions that have been administered.

The first set of items belongs to the institutional factors of schools and how well they supported innovation. This included variables such as innovative working environment (e.g. sample item: ‘Our school does not foster innovation in the classroom’). This included also resources and incentives, that is, time, financial and material resources that the school provided for teachers willing to adopt new approaches to teaching (e.g. sample item: ‘If I get paid for the extra effort, I would spend more effort on systems thinking.’) as well as social recognition (e.g. sample item: ‘If the principal would value my work higher, I would spend more effort on systems thinking.’).
The second set of items belongs to the contextual area of teachers and their motivation, that is, self-efficacy (e.g. sample item: ‘I feel confident to teach systems thinking in my class.’), factors of self-determination (e.g. sample item: ‘Teaching systems thinking, I can emphasize those aspects of it I am interested in the most.’), procrastination (e.g. sample item: ‘It took me days to complete tasks for systems thinking that I originally wanted to do straight away.’), attribution of significance (e.g. sample item: ‘Systems thinking is important for me as a teacher.’) as well as the teachers’ approach towards teaching and learning (e.g. sample item: ‘Teachers should encourage their students to find their own ways of solving a task even this may not be an efficient way.’).

And finally, teaching material was the third set of items. This included the perceived quality of the material provided, that is, the suitability of the systems thinking textbook (e.g. sample item: ‘It is easy to understand and use the textbook’) as well as the questions if there was enough material available (e.g. sample item: ‘If there would be more systems thinking teaching material specific to my subject, I would spend more effort on systems thinking.’).

APPENDIX B: DETAILED RESULTS

Table B.1 Differences between the Groups ‘Voluntary’ and ‘Mandatory’

<table>
<thead>
<tr>
<th>Scales range from 1 (minimum) to 4 (maximum)</th>
<th>Voluntary</th>
<th>Mandatory</th>
<th>T-test (Levené)</th>
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<tbody>
<tr>
<td>Institutional factors of school</td>
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<tr>
<td>Innovative working environment (t2)</td>
<td>N: 44</td>
<td>M: 2.59</td>
<td>SD: 0.63</td>
</tr>
<tr>
<td></td>
<td>N: 68</td>
<td>M: 3.02</td>
<td>SD: 0.44</td>
</tr>
<tr>
<td>Dimensions of incentive (t3):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time and finances</td>
<td>N: 19</td>
<td>M: 1.95</td>
<td>SD: 0.81</td>
</tr>
<tr>
<td></td>
<td>N: 47</td>
<td>M: 1.89</td>
<td>SD: 0.77</td>
</tr>
<tr>
<td>Social and recognition</td>
<td>N: 19</td>
<td>M: 1.89</td>
<td>SD: 0.95</td>
</tr>
<tr>
<td></td>
<td>N: 47</td>
<td>M: 1.68</td>
<td>SD: 0.71</td>
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<tr>
<td>Individual factors of teachers</td>
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<td></td>
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<tr>
<td>Self-efficacy (t2)</td>
<td>N: 44</td>
<td>M: 3.60</td>
<td>SD: 0.37</td>
</tr>
<tr>
<td></td>
<td>N: 73</td>
<td>M: 3.33</td>
<td>SD: 0.39</td>
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<tr>
<td>Self determination (t3)</td>
<td></td>
<td></td>
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<tr>
<td>Experience of autonomy</td>
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<td>SD: 0.42</td>
</tr>
<tr>
<td></td>
<td>N: 38</td>
<td>M: 3.04</td>
<td>SD: 0.61</td>
</tr>
<tr>
<td>Experience of competence</td>
<td>N: 18</td>
<td>M: 3.26</td>
<td>SD: 0.50</td>
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<td></td>
<td>N: 36</td>
<td>M: 2.93</td>
<td>SD: 0.62</td>
</tr>
<tr>
<td>Experience of relatedness</td>
<td>N: 11</td>
<td>M: 2.95</td>
<td>SD: 0.76</td>
</tr>
<tr>
<td></td>
<td>N: 32</td>
<td>M: 2.72</td>
<td>SD: 0.71</td>
</tr>
<tr>
<td>Procrastination (t3)</td>
<td>N: 18</td>
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<td>SD: 0.62</td>
</tr>
<tr>
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<td>N: 37</td>
<td>M: 2.30</td>
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</tr>
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<td>Attribution of significance (t2)</td>
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<td>SD: 0.38</td>
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<td></td>
<td>N: 73</td>
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</tr>
<tr>
<td></td>
<td>N: 35</td>
<td>M: 2.37</td>
<td>SD: 0.60</td>
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</tr>
<tr>
<td></td>
<td>N: 49</td>
<td>M: 2.35</td>
<td>SD: 0.76</td>
</tr>
</tbody>
</table>

Level of significance:
* p < 0.05,
** p < 0.01,
*** p < 0.001.

t1, t2, t3, time of assessment (see also Figure 2); t1, before training and before implementation; t2, after training but before implementation; t3, after implementation.
Table B.2 Differences between the groups ‘Low Implementers’ and ‘High Implementers’

<table>
<thead>
<tr>
<th>Scale range from 1 (minimum) to 4 (maximum)</th>
<th>Low implementers</th>
<th>High implementers</th>
<th>T-test (Levené)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional factors of school</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Innovative working environment (t2)</td>
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<td>28 2.87 0.56</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Dimensions of incentive (t3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time and finances</td>
<td>23 1.86 0.52</td>
<td>32 2.13 0.86</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Social and recognition</td>
<td>23 1.68 0.53</td>
<td>34 1.85 0.91</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Individual factors of teachers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-efficacy (t2)</td>
<td>19 3.26 0.39</td>
<td>28 3.34 0.34</td>
<td>ns</td>
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<tr>
<td>Self determination (t3):</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Experience of autonomy</td>
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<td>$T = -6.19, df = 54^{**}$</td>
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<td>Experience of competence</td>
<td>21 2.65 0.56</td>
<td>34 3.28 0.51</td>
<td>$T = -4.287, df = 53^{**}$</td>
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<tr>
<td>Experience of relatedness</td>
<td>22 2.72 0.53</td>
<td>26 2.83 0.84</td>
<td>ns</td>
<td></td>
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<tr>
<td>Procrastination (t3)</td>
<td>22 2.62 0.62</td>
<td>34 1.99 0.59</td>
<td>$T = 3.775, df = 54^{***}$</td>
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</tr>
<tr>
<td>Attribution of significance (t2)</td>
<td>23 2.93 0.60</td>
<td>32 3.37 0.54</td>
<td>$T = -2.801, df = 53^{**}$</td>
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</tr>
<tr>
<td>Teaching material</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suitability of the systems thinking textbook (t3)</td>
<td>17 2.56 0.72</td>
<td>20 2.81 0.75</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Teaching material (t3)</td>
<td>23 2.42 0.61</td>
<td>31 2.17 0.79</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

Level of significance:
* $p < 0.05$,
** $p < 0.01$,
*** $p < 0.001$.

$t_1$, $t_2$, $t_3$, time of assessment (see also Figure 2): $t_1$, before training and before implementation; $t_2$, after training but before implementation; $t_3$, after implementation.