Evaluating Difficulty Levels of Dynamic Geometry Software Tools to Enhance Teachers’ Professional Development

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This paper describes a study aimed to identify commonly emerging impediments related to the introduction of dynamic mathematics software. We report on the analysis of data collected during a three-week professional development programme organised for middle and high school teachers in Florida. The study identified challenges that participants face during software introductory workshops and evaluated the difficulty levels of the dynamic geometry tools and other features used. Based on the data analysis, complexity criteria for dynamic geometry software tools were developed and commonly occurring difficulties were identified, which provided the basis for the development of several new introductory materials and pedagogy that could assist workshop activities and contribute to the improvement of future introductory professional development workshops with dynamic mathematics software.

1 INTRODUCTION

1.1 Professional Development and Technology Integration

Possessing adequate mathematical skills and knowledge is becoming increasingly important for both everyday life and work. Adler, Ball, Krainer, Lin and Novotna (2005) put “mathematics is viewed as a necessary competency for critical citizenship” (p. 360). This fact amplifies the importance of making quality mathematics education accessible to all students and to improve their mathematics proficiency for life. In order to provide a higher quality education for students, capable teachers who are willing to facilitate creative learning environments are desperately needed (Adler et al., 2005, p. 360). As technologies are becoming used in almost all areas of life they are being integrated into learning environments and offer opportunities to create creative opportunities to learn. Because teachers play a central role in students’ learning, professional development for teachers must be kept up with new opportunities and challenges posed by technology integration. Fostering students’ understanding of mathematical concepts and creating more effective learning environments with technology has recently become one of the main focus areas of ICMI (The International Commission on Mathematical Instruction, 2004, p. 360 – 361).

During the past 25 years, computer technology for mathematics classrooms experienced an extensive growth both in terms of development and availability. This was accompanied by an enormous enthusiasm concerning the potentials of new technologies for teaching and learning mathematics (Fey, Atchison, Good, Heath, Johnson and Kantowski, 1984). Consequently, substantial money was invested into the equipment of schools with hardware, software, and Internet access in order to facilitate an environment that allows technology integration into classrooms (Lawless and Pellegrino, 2007; Cuban, Kirkpatrick and Peck, 2001). In 1992, Kaput predicted that, in regard to the continuing growth of electronic technology, “major limitations of computer use in the coming decades are likely to be less a result of technological limitations than a result of limited human imagination and the constraints of old habits and social structures” (Kaput, 1992, p. 515).

In accordance with Kaput other researchers also began increasingly paying attention to the role that teachers play while trying to enhance students’ knowledge with the use of technology (Lagrange, Artigue, Laborde and Trouche, 2003, p. 257). The authors made an implicit assumption that better teacher performance in terms of mathematical content knowledge, pedagogy, and technology integration in combination with knowledge about research outcomes would sufficiently prepare teachers for an easy and effective integration of new technology into their classrooms. Unfortunately, the situation is more complex than it is highlighted in this assumption and the practical implementation of these goals is quite problematic. Many teachers are still struggling with the task of effectively using technology in their everyday practice and an effective use of technology for teaching and learning mathematics is still rare (Monaghan, 2001).

In summary, solely providing new technologies to teachers does not guarantee its successful integration into mathematics teaching and learning. Appropriate professional development is key to assist teachers in not only the use of new software tools but also introducing a variety of ways by which they could successfully utilise technology in their teaching practices. Furthermore, teachers have to be aware of the increased complexity, compared to their ‘traditional’ classroom settings, of technology-equipped environments.

1.2 Teachers’ Role in the Technology Integration Process

The process of technology integration into everyday teaching is slow compared to high hopes of fast integration in the 1980s (Kaput, 1992). Several research projects aimed to address the reasons behind the slow integration and found that focusing on teachers and their development is crucial for its understanding. The National Council of Teachers of Mathematics (NCTM) expressed in the Principles and Standards for School Mathematics (NCTM, 2000) that: “The effective use of technology in the mathematics classroom depends on the teacher. […] As with any teaching tool, it can be used well or poorly. Teachers should use technology to enhance their students’ learning opportunities by selecting or
creating mathematical tasks that take advantage of what technology can do efficiently and well - graphing, visualizing, and computing” (p. 25).

But what are the possible reasons for teachers’ difficulties in using such powerful tools that have the potential to facilitate their everyday teaching and can provide extensive benefits for their students? Wenglinsky (1998) summarises the challenges for teachers related to the integration of a new tool into teaching as follows: “teachers have historically been resistant to technological innovations when those innovations have made it more difficult for them to get through the typical school day” (p. 8).

Using computers and learning how to work with software tools is definitely a challenge for teachers, especially, if they have no or only little experience with such new technologies. Once they have mastered the basic skills necessary to operate software, there is still a long way to go before they actually are able to successfully integrate it into their usual teaching practices. Although technologies are becoming increasingly accessible in most schools (Cuban et al., 2001, p. 815) many teachers lack the working knowledge (Swain and Pearson, 2002; Lawless and Pellegrino, 2007). In addition, many teachers don’t feel comfortable with using computers for teaching or they do not understand how using technology could possibly assist in providing engaging and meaningful learning environments for their students (Niederhauser and Stodart, 1994). Furthermore, practical constraints such as not having frequent and easy access to sufficient numbers of computers for the entire class (Mousely Lambdin and Koc, 2003, p. 420), or having to deal with unreliable hardware and not being supported sufficiently by technical support staff (Cuban et al., 2001, p. 829), also contribute to teachers’ reluctance of utilising new technologies in teaching.

As mentioned earlier, to ease teachers’ uncomfortable feelings about technology integration providing appropriate professional development and easily accessible teaching materials is necessary. Thus, having such training and easily alterable materials, teachers can focus on modifying their teaching methods and broaden their instructional repertoires in ways that wouldn’t be possible without technology.

2 DESCRIPTION OF THE RESEARCH STUDY

For high quality professional development, “it is important to know in which way a software package can be introduced to novices most effectively” (Mously et al., 2003, p. 401) in order to minimise unnecessary difficulties and impediments during the introduction process for teachers and to facilitate the initial contact with the new software tool as much as possible. Teachers who feel comfortable with operating a new software tool are more likely to integrate this tool into their teaching practices than those who experienced initial difficulties (Mously et al., 2003).

The study described in this article aimed to assess the usability of the dynamic mathematics software GeoGebra and to identify features and dynamic geometry tools in the software that could cause difficulties during its introduction to secondary school mathematics teachers. In this study, GeoGebra 3.0 was introduced to the participants. Findings of the study provide a basis for (1) the establishment of complexity criteria for assessing and categorizing dynamic geometry tools and their difficulty levels to better accommodate needs of novice users in future workshops; and (2) the development and improvement of introductory instructional materials for technology-enhanced professional development (Preiner, 2008).

The study was implemented during a teacher professional development summer institute of a Math and Sciences Partnership project jointly run by the Department of Mathematical Sciences at Florida Atlantic University and the School Board of Broward County funded by the U.S. National Science Foundation. The two-week institute involved workshops introducing a selection of software packages suited for classroom use that the participating in-service middle and high school mathematics teachers may utilise in their teaching when returning to their schools. During the first week of the summer institute, 44 teachers were assigned to three workshop groups and participated daily in four identical 70-minute GeoGebra workshops instructed by one of the authors of this paper. During the workshops, participants used their own laptops and were assisted by several experienced GeoGebra users.

The four workshops evaluated in this study were designed to introduce novice users to the basic use of dynamic mathematics software. As a routine, workshops begun with discussing homework exercises followed by activities designed to introduce best practice examples of using the software for teaching and to foster participants’ independent use of this technology tool. After every workshop teachers were required to complete a short homework exercise. The workshops were evaluated using a series of short questionnaires that allowed participants to rate the difficulty of activities as well as of the dynamic geometry tools and other software features used during each workshop and in the corresponding homework exercises. Furthermore, participants filled in two surveys to assess their computer literacy as well as their mathematics content knowledge, and they had the opportunity to give written feedback and comments about each workshop session. In addition to the questionnaires, workshop assistants completed so called ‘helper report cards’ in which they recorded emerged difficulties during the workshop sessions. A detailed description of the design and content of the introductory workshops, as well as all evaluation instruments can be found in Preiner (2008).

3 SUMMARY OF RESEARCH FINDINGS

In this section, we will particularly focus on the establishment of complexity criteria for dynamic geometry tools and their potential influence on the development and improvement of instructional materials for the introduction of dynamic mathematics software to teachers. Further findings of this study can be found in Preiner (2008) and Hohenwarter, Hohenwarter, and Lavicza (2008).
Based on the feedback and ratings of the workshop participants on a Likert scale ranging from 0 = very easy to 5 = very difficult, the appropriateness and difficulty level of workshops was rated feasible and appropriate for the participating secondary school teachers (average ratings between 1.02 and 2.05). In the written responses, participants indicated that they overall enjoyed the workshops and benefited from its contents. The data analysis also revealed that the hands-on nature of sessions seemed to appeal most to participants and it helped to keep them focused and motivated throughout the summer course. Overall, many participants stated in their open-ended responses that they were most pleased with the usability and versatility of GeoGebra, characterising the software as ‘user friendly’, ‘easy’ and ‘intuitive’ to use, as well as ‘potentially helpful’ for teaching mathematics in secondary schools (Preiner, 2008, p. 88).

Although there were only minor differences between difficulty ratings of geometric and algebraic activities, participants tended to spend about 50% more time on tasks involving algebraic input or the use of commands. The written responses indicated difficulties resulting from learning how to input algebraic syntax, but this was anticipated as earlier studies highlighted the ease of use and intuitiveness of DGS as opposed to the steep learning curve required for computer algebra systems (CAS) (Lavicz, 2008). According to the data collected, external variables such as gender, age, teaching experience, mathematics content knowledge, computer skills, or different computer operating systems did not result in significant differences in any difficulty ratings. Only the use of a touchpad instead of a computer mouse influenced these ratings, with touchpad users rating workshop activities (1.84 versus 1.01), other software features (1.54 versus 0.70), as well as dynamic geometry tools (1.40 versus 0.62) significantly more difficult than users of computer mice (Preiner, 2008, p. 153 – 157).

In order to find out about the most often occurring difficulties, problems, and questions, written responses of participants and workshop assistants were analysed by utilizing constant comparative coding based on the Grounded Theory approach (Strauss and Corbin, 1990). It emerged from the data analysis that participants required assistance in constructing geometric figures, properly using dynamic geometry tools, and inputting appropriate algebraic syntax. These difficulties were collected and provided a basis for the development of detailed guidelines (e.g. introductory book, workshop materials) for future GeoGebra introductory workshops.

4 Difficulty Analysis of Dynamic Geometry Tools

4.1 Subjective Difficulty Ratings by Participants

During the four introductory workshops a total of 21 dynamic geometry tools were introduced. Every day participating teachers rated the difficulty level of all tools used in each workshop on the Likert scale mentioned above. Although the average difficulty ratings of dynamic geometry tools initially was not high (1.8), differences in the complexity of tools had to be noted. Results also suggested strong correlation (Spearman correlation coefficient \( r = 0.894 \)) between the subjective difficulty ratings of tools and activities. Although it is difficult to establish the direction of causality, participants’ and assistants’ written feedback implied that complex tasks negatively influenced tool ratings. This claim certainly needs further examination, but future activity designs should consider simpler exercises while introducing new tools and increase of the task complexity afterwards.

<table>
<thead>
<tr>
<th>Rated Difficulty Level Group</th>
<th>Rating Interval</th>
<th>Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Easy-to-use’ tools</td>
<td>0.48 – 0.99</td>
<td>4 (19.05%)</td>
</tr>
<tr>
<td>‘Middle’ tools</td>
<td>1.00 – 1.35</td>
<td>10 (47.62%)</td>
</tr>
<tr>
<td>‘Difficult-to-use’ tools</td>
<td>1.36 – 1.71</td>
<td>7 (33.33%)</td>
</tr>
</tbody>
</table>

Table 1: Rated difficulty level groups of GeoGebra tools

In order to classify the introduced dynamic geometry tools into three difficulty level groups ‘easy-to-use’, ‘middle’, and ‘difficult-to-use’, as well as to define corresponding thresholds, the difficulty ratings of tools on the day of their introduction were examined. Thereby, critical values for ‘easy-to-use’, ‘middle’, and ‘difficult-to-use’ tools were set at \( t_{easy} = 0.99 \) and \( t_{diff} = 1.36 \) (Preiner, 2008, p. 99-101). Hence, on the day of introduction, four tools were rated to be part of the ‘easy-to-use’ group (19.05%), while ten tools fell into the ‘middle’ group (47.62%), and seven tools formed the ‘difficult-to-use’ group (33.33%, Preiner, 2008, p. 100). However, while the ‘easiest’ tool (** New Point**) was rated with \( x = 0.48 \) on average, even the most ‘difficult-to-use’ tool (\( \square \) Rotate Object around Point by Angle, \( x = 1.71 \)) was rated on average within the lower third of the provided scale. Therefore, none of the introduced dynamic geometry tools seems to have caused major difficulties for the participants.

Figure 1: Comparison of tools ratings on days of introduction and reuse

Overall, about half of the tools introduced in one of the introductory workshops were reused on another day and therefore rated for a second time. Shows both average ratings

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for ten tools, as well as the thresholds for ‘easy-to-use’ and ‘difficult-to-use’ tools. For tool numbers and corresponding tool names see table in Preiner (2008, p. 100). However, after gaining more familiarity with the use of dynamic mathematics software, participants rated all tools as ‘easy to use’ (0.85 or less) regardless of their initial difficulty ratings.

4.2 Complexity Analysis of Dynamic Geometry Tools

In order to analyse the complexity of dynamic geometry tools, common characteristics of the introduced tools subjectively rated to be in the same difficulty group were summarised and the following information was recorded for each tool (Preiner, 2008, p. 110–112):

- the number of actions needed to operate the tool,
- whether or not the order of actions is relevant for a successful use of the tool,
- the number of already existing objects required for the application of the tool,
- the maximum number of different types of objects involved in the application of the tool,
- if some kind of keyboard input is needed in order to use the tool,
- if the tool is the default tool in its toolbox. The icon of a default tool is shown in the toolbar when the software is started.

5 COMPLEXITY CRITERIA FOR DYNAMIC GEOMETRY TOOLS

Based on the subjective difficulty ratings of workshop participants as well as on the analysis of common characteristics of the introduced tools, complexity criteria for dynamic geometry tools were established, that allowed the classification of all GeoGebra tools into three complexity-level groups (Preiner, 2008, p. 120-129). These criteria can also be applied to the tools of other DGS (Preiner, 2008, p. 130-138) under consideration of their potentially different usage in other software packages. The goal of this complexity analysis was to be able to introduce such dynamic geometry tools in a more effective way by considering their underlying difficulty level and trying to prevent common difficulties related to their use.

The following five complexity criteria summarise common characteristics of dynamic geometry tools that are grouped according to their difficulty levels (Preiner, 2008, p. 112–114). The examples given refer to the use of dynamic geometry tools in GeoGebra 3.0.

5.1 Complexity Criteria for ‘Easy-to-Use’ Tools

Criterion 1: The tool does not depend on already existing objects, or just requires existing points which can also be created ‘on the fly’ by clicking on the drawing pad. The order of actions is irrelevant and no additional keyboard input is required.

Example 1: The Segment between Two Points tool meets complexity criterion 1. By clicking twice in order to create two new points or selecting two already existing points, a segment is created between these points. It does not matter which point was created / selected first.

Criterion 2: The tool directly affects only one type of existing object or all existing objects at the same time and requires just one action. Again, the order of actions is irrelevant and no additional keyboard input is required.

Example 2a: The Move tool meets complexity criterion 2. Any free object can be dragged with the mouse by selecting it and holding the mouse key pressed while moving the pointer. Dragging the object is the only action necessary in order to apply this tool.

Example 2b: The Move Drawing Pad tool also meets complexity criterion 2. It does not directly affect a certain object, but all objects in the Graphics View at the same time. Clicking on an empty spot on the drawing pad and dragging it with the mouse is the only action required for the application of this tool.

5.2 Complexity Criteria for ‘Middle’ Tools

Criterion 3: For this tool the order of actions is relevant, but no additional keyboard input is required.

Example 3: The Polygon tool meets complexity criterion 3. Corresponding to the desired number of vertices, several clicks are necessary to create a polygon. The order of clicks is relevant because they specify which of the vertices are going to be connected by segments.

Criterion 4: The tool requires already existing objects of the same type (except just points) or of different types. No additional keyboard input is necessary.

Example 4: The Parallel Line tool meets complexity criterion 4. On the one hand, the tool requires selecting an already existing object in order to specify the direction of the parallel line (e.g. line or vector). On the other hand, a point needs to be selected or created ‘on the fly’ by clicking on an empty spot on the drawing pad in order to specify the distance between the original line and the new parallel line.

5.3 Complexity Criterion for ‘Difficult-to-Use’ Tools

Criterion 5: The tool requires input into a dialog window and usually two or more actions whose order is relevant for a successful application.

Example 5: The Rotate Object around Point by Angle tool meets complexity criterion 5. After selecting an already existing object (e.g. point, polygon), the centre of rotation needs to be defined. Either an already existing point can be selected, or a new point can be created ‘on the fly’. This opens a dialog window where the desired angle, as well as the orientation of rotation can be specified. Thus, three actions, which need to be performed in a certain order, are required in order to successfully apply this tool.
5.4 Tools in Different Difficulty Level and Complexity Groups

Overall, 15 out of the 21 introduced dynamic geometry tools (71%) were subjectively rated by the participants to be in the same difficulty group as the complexity criteria suggest. While five other tools were subjectively rated to be more difficult, only one tool was rated easier than its actual use would suggest. After a thorough examination of these tools, as well as the participants’ feedback and helper report cards, possible reasons for this discrepancy could be found:

- the tool was introduced in the first workshop when participants gathered their very first experiences with the use of the software itself,
- too many new tools were introduced during the same activity,
- the content of activities used to introduce new tools was challenging or unfamiliar for the participants,
- participants did not actually try out a tool themselves, but merely watched the presenter use the tool (e.g. tools \(^\text{Zoom In}\) and \(^\text{Zoom Out}\)).

6 IMPLEMENTATION OF RELEVANT RESULTS

We finally want to summarise, how the results described in this research study could be implemented in future introductory workshops, as well as in the creation and improvement of corresponding instructional materials.

6.1 Suggestions for Future Workshops and Design of Instructional Materials

Workshops should possess a flexible design that allows presenters to respond to participants’ needs and interests by adapting the covered content. Special mathematical topics of different difficulty levels could be offered in addition to the basic software introductory workshop allowing extension of the workshop length and focusing on certain topics.

Since the technical environment and computer skills of participants are different for each introductory workshop, the dynamic mathematics software used should be installed in the beginning of the workshop in order to familiarise participants with this process. Also, all necessary files (e.g. construction files, picture files) should be downloaded and saved on participants’ desktops to ensure easy access during the workshop activities.

The presenter should encourage participants to use a computer mouse with their notebook computers to enable easier operation of the software and prevent unnecessary problems. Therefore, a set of computer mice could be brought along by presenters that can be borrowed by participants.

The amount of mathematical content covered in the workshop should not overwhelm participants. Hence, small portions of information should be initially given, followed by some practice time that allows participants to process the new knowledge and to practice their new skills. During these practice blocks, a pool of activities could be offered containing tasks of different difficulty levels ranging from basic applications to challenging tasks.

Mathematical concepts, construction processes, and properties of geometric figures need to be clarified prior to activities in order to prevent additional difficulties when using dynamic mathematics software for the first time.

In order to introduce new dynamic geometry tools, less complex activities should be used first. The number of tools introduced in each activity needs to be kept rather low and the participants should be allowed to try new tools prior to working on the assigned activities. Tasks that combine algebraic input and the introduction of new tools need to be treated with special care, because they are more complex and tend to cause additional difficulties. In order to emphasise common characteristics as well as differences between similar tools (e.g. tools \(\text{Perpendicular Line}\) and \(\text{Parallel Line}\)), such pairs of tools should be introduced during the same activity with their relation explained prior to actually using them within constructions.

New dynamic geometry tools always should be introduced according to their complexity group classification. ‘Easy-to-use’ tools can be explored and tried independently by participants to foster their independent use of the software at home. The use of tools assigned to the ‘middle’ group could be demonstrated by presenters and their characteristics explained (e.g. order of clicks, types of objects required) while participants are encouraged to simultaneously work along. Finally, ‘difficult-to-use’ tools should be thoroughly discussed prior to actually using them in order to prepare participants for different actions required for successful application of tools. Presenters must pay special attention to required keyboard input allowing time for practicing using those tools afterwards.

Participants should learn how to properly activate a tool whose icon is already shown in the toolbar, as well as how to select appropriate tools for every construction step. Additionally, reading provided tooltips or the Toolbar Help in order to find out how the selected tool can be operated needs to be emphasised throughout the workshop to prepare participants for using the dynamic mathematics software independently. The connection between tools of the same toolbox should be explained as to facilitate finding desired tools in the toolbar.

Hands on activities and discussions are important parts of an introductory workshop and these should be emphasised. Additionally, a variety of best practice examples could be presented in order to familiarise the teachers with ways of using dynamic mathematics software with their students and helping them to transfer their new skills to classrooms.

Proper documentation should be provided at introductory workshops, including detailed handouts,
construction protocols for geometric constructions, a summary of all dynamic geometry tools used, their assignment to certain toolboxes, as well as explanations on how to use them, a description of menu items and corresponding features (including explanations for features with multiple options), detailed information about the syntax of algebraic input and commands including an overview of the most common mistakes and error messages.

6.2 Development of New Instructional Materials for GeoGebra Introductory Workshops

Based on the findings and the described suggestions, a series of GeoGebra workshop materials that cover about 2 to 3 hours each has been developed with the aims (1) to increase the awareness of most common mistakes/difficulties novices face during the introduction of dynamic mathematics software and (2) to prevent common impediments in future workshops and make the introduction process easier for novices.

These workshop materials consist of printable workshop handouts and files for participants, as well as a so-called workshop guide and presentations for presenters. These new professional development materials cover the use of basic tools and features of the software, demonstrate possible ways of integrating the software into everyday teaching, the creation of own instructional materials, as well as the use of advanced features which have not been part of the assessed introductory workshops. Each of the workshop handouts was created to also support users who want to get to know GeoGebra without participating in an introductory workshop guided by an experienced trainer. In general, these materials contain:

- **detailed instructions** as well as tips and tricks that might prevent commonly occurring difficulties and problems,
- so-called ‘**guided activities**’ that are explained step-by-step, as well as ‘**practice activities**’ that require more independent use of the software,
- **discussion questions**, that require more thorough thinking about certain aspects and might foster in-depth understanding,
- so-called ‘**Back to School activities**’, that demonstrate how students might experience and could benefit from the use of dynamic mathematics software and corresponding interactive applets so-called **Dynamic Worksheets** (Preiner and Hohenwarter, 2007),
- **best practice examples**, that explain potential ways of integrating technology-enhanced activities into everyday classroom teaching,
- **challenge activities**, that only provide little instructions and require highly independent use of the software.

All instructional materials described above are available online for free download at [http://www.geogebra.org/help](http://www.geogebra.org/help) under ‘**Workshop Materials**’. While the participant package contains all the workshop handouts as well as necessary files (e.g. GeoGebra construction files, dynamic worksheets, picture files), presenter materials also come with a workshop guide, ready to use presentations and editable versions of the workshop handouts. All these materials are under a Creative Commons Attribution, Non-Commercial, Share Alike license ([http://www.geogebra.org/en/cc_license/cc_license.htm](http://www.geogebra.org/en/cc_license/cc_license.htm)) that allowed their translation into different languages as well as their adaptation to the local needs of teachers in different countries.

7 CONCLUSIONS AND FURTHER RESEARCH

The process of successful integration of technology into mathematics teaching and learning is progressing slowly and turned out to be rather complex. Today many teachers and students have access to computers and although appropriate software is available both in schools and at home, technology is rarely integrated substantially into everyday teaching. Being aware of the vital role that teachers play in technology-supported mathematics classrooms, professional development opportunities need to be adapted in order to better prepare teachers for new challenges of integrating technology into their teaching practices.

The study described in this paper represents an initial step towards the goal of providing more successful introductory materials for professional development with dynamic mathematics software through identifying impediments that teachers face when being introduced to this new technological tool. For different reasons, like its open-source nature and versatility, the dynamic mathematics software GeoGebra was selected from the pool of available educational mathematics software in order to evaluate a series of introductory technology workshops and assess the usability of the software itself, but results of this study could be also applied to other dynamic mathematics packages. Based on the findings, complexity criteria for dynamic geometry tools were defined to determine the general difficulty level of construction tools. They could be useful for redesigning the ‘traditional’ introduction process of dynamic geometry tools and adapting the way in which they are presented to novices. New instructional materials have been developed and existing instructional materials for professional development have been modified with the goal of making the introduction of dynamic mathematics software easier for mathematics teachers.

In the case of the dynamic mathematics software GeoGebra, this approach is currently being implemented in the design of new introductory workshops and accompanying instructional materials for presenters as well as workshop participants. By preventing frequently occurring difficulties in terms of software use and design of workshop activities as well as incorporating characteristics of high-quality professional development, the first contact of mathematics teachers with dynamic mathematics software is expected to be easier and more effective than in previous technology workshops. In order to set a high quality standard for professional development events with GeoGebra, follow-up application workshops as well as additional documentation and instructional materials about the software and its integration into mathematics classrooms are currently being developed.

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Based on the outcomes of the evaluation of introductory workshops and the usability of GeoGebra, further research studies could be devised in order to:

- evaluate the newly designed introductory workshops in terms of usability, effectiveness, and relevance for teachers,
- assess the quality of documentation, instructional materials, as well as professional development,
- collect data about the usability of GeoGebra that provides a basis for further developments of the software and increases its usability for both teachers and students,
- assess the level of effective integration of dynamic mathematics software into mathematics classrooms as well as its potential impact on instructional methods, classroom settings, instructional materials, and mathematical content taught,
- assess the potential influence of dynamic mathematics software on students’ learning and understanding of mathematical concepts.

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REFERENCES


NCTM (2000). *Principles and Standards for School Mathematics*. NCTM.


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