Tell, Draw and Code – Teachers' Intention to a Narrative Introduction of Computational Thinking

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Abstract. The increasing importance of introducing computer science and computational thinking in primary education highlights the need to prepare teachers adequately. This study reports on professional teacher training in programming. It draws on the Technology Usage Inventory (TUI) model to investigate how an interdisciplinary intervention with programmable robots, combined with the storytelling method, can influence the intention to use them in the classroom. Special focus is given to the Tell, Draw & Code method to offer teachers a didactic concept for implementation. The floor robots used in this study are Bee-bots. At the beginning and end of the teacher training course, the participating teachers completed a questionnaire about their perceptions, attitudes, and intentions about using robots in the classroom. In addition, after designing and implementing activities with robots, the teachers provided qualitative reflections on their experiences. In comparing pre-and post-test and the analyses of the qualitative data, the study shows a significant increase in the positive attitude towards using the robots. These findings highlight the need for teachers to have opportunities to explore, reflect on and experience the potential of new technologies as part of their teacher development to implement innovations sustainably.

Keywords: Computer science education · Educational robotics · Primary school · Professional teacher development

1 Introduction

Emphasis on problem-solving thinking and the introduction of computer science education for young learners have been increasing worldwide. To integrate computer science education in primary schools, in Austria, there is currently only the recommendation of the digikomp4 model [1], which serves as a reference framework and orientation guide for equipping primary school students with appropriate digital competencies up to the 4th grade. However, it is planned to anchor computer science education in the primary school curriculum in autumn 2023 [2]. Educational robots as a didactic tool offer one possibility of getting introduced to the first steps of computer science education and promoting computational thinking skills [3].

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However, Austrian primary school teachers' knowledge of programming and programming didactics is limited. Although the topic has gained importance in recent years and research also attests to positive effects, there are still only a few singular initiatives in Austria dealing with programmable robots [4]. This situation has led to the case that the primary school teachers have limited support in didactic knowledge and good examples. But an essential aspect of implementing innovations in the education system is the willingness of teachers [5]. Furthermore, good training is necessary.

In the 2018/19 school year, all state kindergartens and primary schools in the province of Lower Austria - a total of 1,700 locations - were equipped with Bee-bot sets. The set consists of four Bee-bots, two Blue-bots, and two Tac Tile readers. Although at the beginning to offer training to teachers, two years later, there are still many schools where the Bee-bots are unfortunately stored unused in a box. One reason for this is undoubtedly the limited use during the Corona pandemic. Furthermore, skepticism and lacking knowledge about how to integrate robots in teaching could be why they are not used. To solve this situation, a project was developed that deals with programmable robots' interdisciplinary use combining the storytelling method in primary schools. This paper presents a teacher training course that consisted of a workshop followed by an asynchronous online phase. Since the training was attended by teachers who had little or no experience with programmable robots, the aim was to provide them with didactic possibilities and examples of an interdisciplinary approach to familiarize the students with simple concepts of computer science teaching. The study aims to answer the following questions:

RQ1: To what extent do interaction and teaching with programmable robots influence primary school teachers' intention to use robots in their classrooms?
RQ2: What are the teacher's perspectives of the intervention using robotics-based storytelling activities?

2 Background Work

2.1 Educational Robotics in Pedagogical Context

Digitization is postulated in all areas, especially in education. The responsibility of education is to teach students to become problem-solving, creative, and collaborative personalities [6]. Learning and innovation skills teach students the mental processes required to adapt to and improve a modern working environment. A focus on creativity, critical thinking, communication, collaboration, and computational thinking is essential to prepare students for the future [7]. Computational thinking [3] should already be promoted in primary school to develop one's solution strategies reflectively and solve the problem according to the scheme of an algorithm. Computational thinking (CT) can be understood as a problem-solving process [8] and should encourage pupils to apply this competence in everyday life. Programmable robots are increasingly part of everyday school life to acquire competencies in the field of digitization. Most of them are floor robots, which are being used and tested as learning media in more and more schools. Aspects of robotics and general media use can be introduced to the learners in this way and the technical and content-related competencies.

Educational robotics (ER) can be an effective way to introduce computational thinking. Students can systematically complete tasks and develop the sequenced step-by-step coding commands required to program a robot [9]. Benitti [10] investigated the educational potential of robotics in schools, identified how robotics could contribute by integrating it as an educational tool in schools, and examined its effectiveness. The use of programming tools provides young learners important computational approaches to addressing real-world problems [11]. Nouri et al. [12] investigated teachers' experiences with Bee-bots and Scratch. Their study identified the promotion of CT skills, digital literacy, and 21st-century skills, language skills, collaborative skills and attitudes, and creative problem-solving skills. The successful integration of robotics into the school classroom depends on the robot itself, the activities selected, and the material designed [13].

2.2 The Bee-Bot

The robot used in this study is the Bee-bot. This tangible robot allows students to initiate their coding skills [14]. They are especially suitable for young learners by promoting haptics and introducing them to computational thinking [4]. A Bee-bot is a very simple floor robot that represents a bee without wings. Seven buttons on the back program it. The programming is done with the key forward, backward, left turn, right turn, pause and delete. The program sequence is not started until the GO key is pressed. The steps to the destination must be well thought out and planned.

Nevertheless, its easy handling and the fact that it makes programming tangible for children makes the Bee-bot particularly suitable for encouraging problem-solving thinking [15]. Schina et al. [13] showed in their study that Bee-bots are not only helpful in promoting problem-solving thinking but can also be beneficial for children with attention deficits and dyslexia. Furthermore, the same authors reported that teachers mentioned that "the robot toys have various applications in foreign language teaching (in grammar and vocabulary)" [13, p.10].

2.3 Professional Teacher Development

The increasing demand for CT in K-12 education [16] and the introduction of computer science education in primary education have highlighted the need to prepare teachers with the technological, pedagogical and content knowledge (TPACK) necessary for teaching CT [17]. Many efforts have emerged to prepare teachers to teach coding [18]. Primary school teachers face a variety of obstacles when teaching CS. Teachers may meet many barriers, such as a lack of computers or reliable Internet access, and institutional obstacles in the form of unsupportive principals, lack of legislation, and emotional barriers, including beliefs, attitudes, and dispositions that hinder the use of technology [19]. To integrate these innovations into primary education, teachers must have the required knowledge, self-confidence, and a positive attitude [20] towards this concept. Regarding teachers' acceptance of robots in education, Chevalier et al. [21] highlight that intention to use robotics in the classroom increases when teachers are provided with appropriate teacher training, didactic approaches, and pedagogical materials that can be used directly. To teach coding, they must be well-prepared, and the training program must build self-efficacy and address teacher's beliefs in importance and applicability [19]. Concerning teacher development and its relation to CT Kong [17] considers a lack of high-quality research. Angeli et al. [22] provided a conceptualization of TPACK for the construct of CT. However, this conceptualization focuses on the knowledge necessary to teach courses aligned to a specific didactic design independently. However, for any new educational technology to be successfully implemented and used in K-12 classrooms, teachers must be aware of new educational technology tools available, accept the technology as having practical benefits, feel confident that the technology is easy to use. They should have confidence in their ability to use the technology [5] and have opportunities for experimentation to minimize risks. In innovation research [23], it is assumed that the more the factors mentioned are fulfilled, the more reliably and quickly innovation is adopted and spread. In addition to the factors already mentioned, Kong et al. [16] recommend that effective teacher development take place over an extended period of time. The school context and opportunities for practice and reflection are essential, with the best development occurring when there is an opportunity for sharing. Also, Schina et al. [24], in their literature review on teacher training in the ER context, recommend that teachers should be given the opportunity to put their technical and pedagogical knowledge of robotics and programming into practice in the classroom.

3 Conceptual Framework

3.1 Technology Usage Inventory

In assessing teachers' attitudes towards using programmable robots as an introduction to computer science education, the Technology Usage Inventory (TUI) questionnaire developed by Kothgassner et al. [25] was used. This survey instrument is a further development of the technology acceptance questionnaire by Davis [26] and Venkatesh and Davis [27]. The further development mainly concerns psychological factors which are not sufficiently considered in the instruments used so far. The original procedure contains the following eight scales: Curiosity, Anxiety, Interest, Ease of Use, Immersion, Usefulness, Skepticism, and Accessibility [25]. Their internal consistencies range from $\alpha = .70$ to $\alpha = .92$. An adapted form of the questionnaire was used, as the scale "Immersion" was not relevant for this study. Instead, the scale "Necessity" ($\alpha = .92$) was added.

3.2 Teacher Training Course

At the beginning of the training, the participants were given theoretical knowledge about the programmable robot and informatics concepts that can be implemented using the Bee-bot. After that, they were familiarized with the programming commands and the functioning of the yellow floor robot. One difficulty was to provide practical experience with the Bee-bot, as all classes at the university were only held online due to the Corona pandemic. However, since all schools in Lower Austria were equipped with Bee-bots, some participants have a Bee-bot at home and use it to do the exercises.

The trainer transmitted the Bee-bot's functioning with the document camera so that all could at least see the Bee-bot. The participants were shown videos that were still filmed in the classroom using the programmable robot. Moreover, the participants had further practice opportunities using the Bee-bot simulator[1] and the Bee-bot App. This setting made it possible to simulate the robot's functioning very well, and there was no disadvantage due to the online situation.

The second part of the training consisted of offering the participants possibilities for the interdisciplinary use of the Bee-bot. Above all, they were introduced to the didactic design of the Tell, Draw & Code method.

3.3 Didactic Design – Tell, Draw and Code

The didactic design chosen was an approach called Tell, Draw & Code by the authors. This method aims to implement computational thinking in connection with creative narrative and writing processes. In introducing simple programming languages, literary texts become a vehicle for coding and decoding language. First, the students' task is to read a text or invent a story, and then they reproduce it graphically. They have to create a map with the story or put the pictures on the map, e.g., they place parts of a picture story so that the Bee-bot will move along the story if it has been programmed correctly. The students can use as many commands as necessary. The Bee-bot can execute a maximum of 40 commands in a row. The text is structured through graphic representation, and through practical action, the storyline is constructed. By retelling the story or tale, the text is decoded again. This transformation requires problem-solving strategies by breaking down the problem into smaller steps or applying known patterns, as described in several computational thinking frameworks [8, 11]. The dialogic negotiation of computer science problems combined with creative representations of the stories in visual form should sustainably promote the children's narrative language. At the same time, the structuring and coding of the text should also give children with reading and spelling difficulties the opportunity to deal with the individual sections of the story in greater detail through programming. Initial successes have already been recorded with the Ozobot [28]. Tell, Draw & Code can be applied to the following settings:

- Retelling stories or fairy tales
- Creating stories
- Taking information out of a text and presenting it
- Getting to know children's literature.

4 The Study

4.1 The Participants

The quasi-experimental pre-post-test study occurred within a teacher university course.

The participants took part in a course consisting of six modules and lasting two semesters. This university course aims to provide teachers with knowledge about digital basic education and concepts for effective implementation in primary education. One

[1] https://beebot.terrapinlogo.com.

module called "Developing problem-solving strategies" teaches introduction to computer science education, particularly the development of computational thinking, i.e., the promotion of problem-solving competence, and how it can be implemented, for example, with programmable robots. This training consisted of a live workshop held online due to the Corona pandemic and an asynchronous online phase over seven weeks, which took place via a learning platform. The participants are introduced to the Bee-bot, the Blue-bot, and Ozobot robots and shown how to use programmable robots in the classroom. As part of this module, their task was to plan, implement and reflect on an interdisciplinary teaching unit. Afterward, they had to report their experiences and findings in writing.

The participants (n = 16) of the study were primary school teachers; 14 women and two men. Most participants were between 30 and 40 years old. They teach classes from grade 1 to grade 4.

4.2 The Survey

Pre-and post-test were conducted by using an online questionnaire on the LimeSurvey platform. The pre-test questionnaire consists of 31 items, 2 relate to demographic data and 29 to the TUI model. The post-test consists of 31 items, 2 demographic questions, 24 related to the TUI model, and 5 items related to acquired competencies. The four-part Likert scale (4 = strongly agree, 3 = agree, 2 = disagree, 1 = strongly disagree) was chosen as the response format. In addition, the post-test questionnaire contains an open question on the experiences made using the programmable robots. 14 of the 16 participants completed both questionnaires, 12 female and 2 male participants.

The quantitative data were analyzed with descriptive statistics using SPSS 26. The scales INT, SKE, ETU, USE, NEC, ITU were used to examine a change in participants' attitudes before and after the intervention. The t-test was applied to compare significant mean values. This test is particularly suitable for comparing two dependent samples [29]. The participants' reflections provided the data for the qualitative results after the implementation of the intervention. The statements were coded and analyzed using a qualitative content analysis [30]. They offered insights into the teacher's perspectives of the intervention and the students' competencies promoted through these settings.

5 Results

The presentation of the results is organized as follows. First, two examples of the lessons designed by the participating teachers are presented. Then, the quantitative survey results are presented, which investigated how interaction and teaching with programmable robots influence primary school teachers' intention to use robots in their classrooms. Finally, the question about the experiences and perspectives is answered.

5.1 Lessons

This chapter provides two examples of the lessons where the participants implemented the Tell, Draw & Code method. For lesson planning, most participants opted for the

Bee-bot. Two teachers used the Blue-bot. The teachers reasoned their choice that these robots were available at their school.

Creating a Story: The task of the Year 2 pupils was to write a picture story. In this case, they were given six pictures, which they had to put in the appropriate order to make a meaningful story. Then the story was programmed with the Bee-bot. At the same time, the students told the plot of the story to the other children. Afterward, the story was written down in the exercise book.

Retelling a Book: The book "The Gruffalo" was read to the students (Fig. 1). When an animal was named, a child programmed the Bee-bot to move on to the respective picture card of the animal. In the end, the story was retold.

Fig. 1. The Gruffalo

5.2 Evaluation Pre-/Post-test

To answer the research question (RQ1), to what extent do interaction and teaching with programmable robots influence primary school teachers' intention to use robots in their classrooms, a pre-post-test was conducted.

The pre-test was carried out right at the beginning of the workshop. First, the participants were asked which of the three robots presented they were familiar with and whether they had already tried them out. All participants who correctly completed the questionnaire (n = 14) knew the Bee-bot, but only six of them had already tried it out. Only six teachers knew about the Blue-bot, and none had had any experience with it. The post-test was conducted after the course and the intervention. Analyzing the descriptive data of both tests it was surprising that the intention to use (ITU) already showed a very high value in the pre-test (M = 3.50/SD = 0.58) and that this value increased even more in the post-test (M = 3.73/SD = 0.27). Ease to Use (ETU), pre-test (M = 3.0/SD = 0.72) and post-test (M = 3.60/SD 0.47) and Necessity (NEC), pre-test (M = 3.26/SD = 0.63) post-test (M = 3.61/SD = 0.57), also showed high ratings.

The post hoc paired samples t-test (Table 1) was used to compare pre- and post-test changes in teachers' attitudes after learning about the Tell, Draw & Code method and after the intervention.

Table 1. Post hoc paired sample t-test

Variable	Mean difference	SD	t	df	Sig.	Cohen's d_Z
ACC	0.191	0.855	0.834	13	0.419	0.222
INT	0.304	1.020	1.114	13	0.286	0.298
NEC	0.357	1.008	1.325	13	0.208	0.350
SKE	−0.179	0.717	−0.093	13	0.927	0.025
ETU	0.536	0.720	0.192	13	0.015	0.745
USE	0.643	0.891	2.699	13	0.018	0.721
ITU	0.238	0.646	1.379	13	0.191	0.368

Table 1 shows a significant difference between teachers' combined robot-related attitudes and intentions before and after the intervention. Particularly significant differences are found in the variables *Ease to Use* (ETU) (s = 0,015/d = 0,745) and *Usefulness* (USE) (s = 0,018/d = 7,21). Hence, this test shows that the participants' increase in these variables can be explained reliably by the intervention carried out.

5.3 Qualitative Findings

The second research question (RQ2), what are the teacher's perspectives of the intervention using robotics-based storytelling activities and what students' competencies were identified, was determined qualitatively. 15 of the 16 participants in the course planned a lesson implementing programmable robots, conducted it, and reflected on it in writing.

Table 2 shows the teacher's perspectives of the intervention using robotics-based storytelling activities. Although they were skeptical about the usefulness and necessity of educational robotics in teaching at primary school initially, all participants (n = 15) were enthusiastic after the course. There was only positive feedback. Although all the participants have known the Bee-bots, their experience lacked so far. They also reported not having had any appropriate concepts and didactic approaches until now. "Until today, I have not known how to use the robots in a meaningful way" (T_11).

Most of the participants were aware of the Bee-bots because they are available at the school. But the teachers lacked experience so far. They also reported not having had any appropriate concepts and didactic approaches until now. "Until today, I have not known how to use the robots in a meaningful way" (T_11). The participants reported that they were delighted that they finally had to try out the Bee-bots. They also stated that actively interacting with Bee-bots during teacher training's task plays a crucial role in their positive attitude towards them. Ten participants (66.7%) reported that they now have relevant knowledge. "I was able to take away fascinating ideas and didactic approaches from this course, and I am happy that I was able to try out the Bee-bots" (T_5). "I probably would not have used the Bee-bots without this course. Now I am convinced that they can be used successfully in the classroom" (T_10). 73.3% of the participating teachers were particularly enthusiastic about the playful and simple programming and the children's immediate sense of achievement. One teacher reported: "I am delighted that I was finally able to get to know the Bee-bot better. This made me realize that programming the bee is more difficult for adults than for the children" (T_3). "The children programmed without any problems, and each unit was a great success" (T_5). "The effort is shallow, and the learning success is enormous" (T_8).

Table 2. Teachers' perspectives of the intervention using robotics-based storytelling activities

Codes	Example of statements	F	%
Causing joyful learning	The children were very enthusiastic and programmed great stories (T_15)	11	73.3
Providing playful and simple programming	The children soon understood how to program the robot (T_5)	10	66.7
Supporting the learning process	The students have never learnt so many words before (T_6)	4	26.7
Fostering problem-solving thinking	I was observing how the students playfully developed problem-solving strategies (T_10)	8	53.3
Promoting teamwork	I was very fascinated how the children worked respectfully in the group and supported each other (T_12)	13	86.6
Promoting reading and narrative skills	By programming the story, special attention was paid to detailed retelling of the story of the Gruffalo (T_8)	7	46.7
Fostering spatial thinking	Spatial orientation was greatly enhanced by programming the paths of the Bee-bot (T_6)	5	33.3
Providing an appropriate didactic approach	I was able to take away fascinating ideas and didactic approaches from this course (T_5)	10	66.7

Seven participants (46.7%) also confirmed that the promoting of reading and narrative skills plays a big part. Since the students spoke a lot during programming and when creating the stories. "The children also spoke aloud during programming" (T_6). The method of storytelling was also very well received by the participants because "the children are even more motivated to tell stories through the Bee-bots" (T_5). "The children made up different stories and were happy when the bee successfully followed the right path. In doing so, they retold the story" (T_15). They described in the reflections the method as very purposeful and motivating. "Narrative skills were fostered playfully" (T_8).

According to the teachers, this interdisciplinary use of robots can promote problem-solving thinking very well. 13 participants (86.6%) mentioned this aspect by using educational robotics combining storytelling activities. "I was able to observe the strategy development of individual pupils, and it also became clear who still had problems with foresight and logical thinking. But by helping each other, everyone was able to develop further" (T_8). Mainly (86.6%), teamwork was highlighted as very positive: "They helped each other appreciatively in the group so that everyone had a sense of achievement with the Bee-bots in the end." (T_14).

Four teachers (26.7%) stated that Bee-bots supported the learning process very much in the subjects. In English classes, many children naturally learned and used more vocabulary than before" (T_14).

Four teachers passed on their knowledge to their colleagues in a conference. One teacher reported that "other teachers have also acquired a taste for it" (T_12). The teachers also agreed to continue using the robots. "I am totally enthusiastic about how much fun and motivation the bee has provided and will definitely use this teaching tool more often" (T_4). "I can only recommend working with these programmable robots" (T_10).

5.4 Discussion

The results of the study show that the use of learning robots in primary school is very motivating. Furthermore, storytelling in combination with programmable robots is a promising didactic method to introduce computer science education in primary school in an interdisciplinary approach, extend the language in creative activities, and use it to develop problem-solving strategies. Specifically, this setting supporting computational thinking skills offers a replicable learning design for teachers. The study also demonstrated that it is essential to actively try out new methods, such as losing one's fear of programming and being better able to judge whether one is convinced of it. Trying out the robots, getting to know didactic applications, and the practical implementation [16] of the method during the teacher training leads to an increase in attitude regarding the intention to use [25]. This study also highlights the importance of equipping teachers with pedagogical, technical and content knowledge [17], as well as self-confidence and a positive attitude [20], to implement computer education and achieve an approach to computational thinking.

The innovative use of programmable robots notably promoted the willingness to tell stories. Before storytelling, the practice phases showed a high potential for intensive independent engagement with the programming language. For the students and teachers involved in the intervention, informatic skills emerged that could be taken up and developed in other narrative and writing projects. The innovative approach of linking narrative language, visual language and programming language through Bee-bots can thus be sustainably introduced into everyday school life. It shows that computer science lessons can be realized as interdisciplinary competence development through the new curriculum.

6 Conclusion and Future Work

This study contributes to understanding teachers' attitudes towards using robots in primary education and the usefulness of robots in the classroom. This understanding can contribute to gaining knowledge about implementing computer science education and more positive attitudes towards robotics integration. The method Tell, Draw & Code is dedicated to integrating programmable robots for developing traditional narrative and writing skills. Engaging in creating one's own stories or examining literary texts found in children's books and controlling the robots in a challenging and motivating way can lead to synergies in the learning process. The stories come alive in a particular way by changing the written language to visual language and spoken language.

This study provided empirical evidence that the teacher training program effectively changed participants' skills and attitudes. The evaluation was based on objective tests and self-assessments, overcoming problems related to initial skepticism. By designing and implementing the Tell, Draw & Code method, teachers can experience a pedagogical model that they can implement in their primary school teaching. Based on the available findings, we can validate that ER teacher training courses are effective, if the teachers are offered appropriate didactic concepts [21], if they last longer and the participants then also have the opportunity to exchange ideas [24], if they can gain practical experience in lesson planning and in implementing the robot activities when teaching [13]. By bringing in own ideas, the familiarity with the method is increased even more.

Future work is planned to study teachers' attitudes towards implementing and using the Tell, Draw & Code method specifically with Ozobots only and comparing the results with the research presented here.

Appendix

(See Fig. 2 and Table 3).

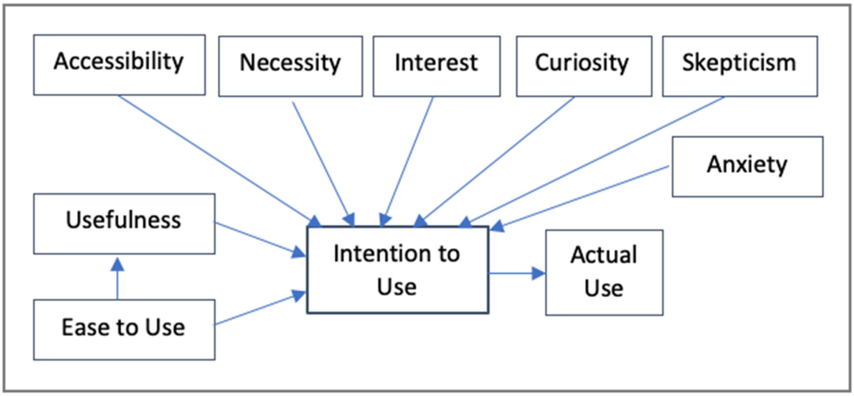

Fig. 2. TUI Acceptance model by Kothgassner et al. [25] (adapted version)

Table 3. Scales and internal consistencies

Scale	Variable	Items	Cronbach's Alpha
Anxiety	ANX	4	0,83
Curiosity	CUR	4	0,87
Interest	INT	4	0,86
Skepticism	SKE	3	0,70
Ease to Use	ETU	3	0,74
Usefulness	USE	2	0,70
Accessibility	ACC	3	0,86
Necessity	NEC	3	0,92
Intention to Use	ITU	3	0,84

Table 4. Descriptive data of pre-and post-test

Variable	Time	Items	M	SD	MIN	MAX	VAR
INT	Pre	4	2,66	0,81	2,36	3,36	0,22
	Post	4	2,96	0,74	1,50	4,00	0,55
SKE	Pre	3	1,74	0,66	1,36	2,00	0,03
	Post	3	2,05	0,52	1,00	3,00	0,27
ETU	Pre	3	3,04	0,72	3,00	3,07	0,00
	Post	3	3,60	0,47	2,67	4,00	0,23
USE	Pre	2	3,29	0,58	3,21	3,36	0,01
	Post	2	3,29	0,37	3,00	4,00	0,14
ACC	Pre	3	2,57	0,77	2,43	2,79	0,04
	Post	3	2,76	0,55	2,00	3,67	0,30
NEC	Pre	3	3,26	0,63	3,22	3,23	0,01
	Post	3	3,61	0,57	2,33	4,00	0,32
ITU	Pre	3	3,50	0,58	3,29	3,64	0,04
	Post	3	3,73	0,27	3,33	4,00	0,04

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