JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898

SUPPORTING INQUIRY BASED LABORATORY PRACTICES WITH MOBILE LEARNING TO ENHANCE STUDENTS' PROCESS SKILLS IN SCIENCE EDUCATION

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Abstract. *Supporting the latest technology for inquiry is among one of the topics that is currently being discussed in the context of science education. The aim of this research is to examine the laboratory practices that use mobile learning to enhance the science process skills of the participants. The research is of qualitative design and has been planned as action research. The practices on determining the quality of water are based on an approach of guided inquiry based learning. The research was conducted with eleven (n=11) volunteering pre-service teachers who were third-year students in department of the science teacher education. Group discussions, classroom camera records and spreadsheet responses were used to determine the scope of the research. The data were analyzed with directed content analysis by two separate researchers who used the Nvivo 8 program. At the end of the research, it was concluded that using mobile learning contributed to the laboratory practices in many ways.*

Key words: *inquiry based laboratory practices, mobile learning, science process skills, and water quality.*

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Introduction

Technology is an essential part of everyday life for today's students, as meaningful for them as meeting their physiological needs. From early on in childhood, learning processes, communications, concepts of entertainment are shaped within the framework of advancing technologies. Prensky (2001), in his work "Digital Natives, Digital Immigrants," refers to today's students as digital natives and to teachers as digital immigrants. Although the concept of digital natives is debated whether it is scientifically premature (Bennett, Maton, & Kervin, 2008), the concept was already settled in the scientific language. The concept refers that they are dependent on communication technologies for accessing and for interacting, and these technologies quickly become a part of their lives. They are more interested than their parents and teachers for newly released technologies. This provides educators with the opportunity to create new learning environments for the future. The computer skills of students cross over ethnic, language, gender or socioeconomic borders and are a real asset that can be gained without the guidance of an adult (Dangwal, Jha, Chatterjee, & Mitra, 2005; Mitra, & Dangwal, 2010). In this context, the expectations of these students from education go beyond learning technology, moving more into the realm of how to make use of technology as a tool in the learning environment. Educational curriculums support this goal. The content and practices of Next Generation Science Standards (NGSS) recommends the broad use of technology in various ways.

> "Such tools need to be used purposefully to advance particular learning goals, for example, to help students engage with real data, investigate phenomena or work with and communicate their models. In particular, the practice of computational thinking involves such activities as simulations to model physical phenomena or test engineering designs under a range of different conditions, to mine existing databases, or to use computer-aided design (CAD) software to design solutions to problems… (NRC, 2015)"

It is important that practices are appropriate to the digital medium, both in terms of knowledge and of skills. When compared with lessons in which these are not used, practices that use technology effectively can be seen to be more meaningful for students. In today's world, the category of low-cost simple devices includes the smart phones that everyone has in his pocket or bag. It is for this reason that the scope of benefiting from technology in the learning environment has broadened immensely. In the light of this perspective, the research explores the support of mobile learning in doing two science laboratory practices that have been designed within the framework of inquiry based science education. The goal of this research has been to show that the inquiry based laboratory practices supported with mobile learning will make process skills more effective, both in terms of basic process skills as well as integrated process skills. The research seeks answers to the following research questions:

- How can inquiry based laboratory practices be supported by mobile learning?
- How can mobile learning be used to make students' process skills more effective?

Mobile Learning

The Ambient Insight Research (2015) classifies learning technologies into a wide range of products: Self-paced eLearning courseware, digital reference-ware, collaboration-based learning, simulation-based learning, game-based learning, cognitive learning, and mobile learning. Mobile devices (smartphones, mobile computing, probes attached to hand-held computers, etc.), which occupies an important place in mobile learning, presents science education with a new area of development that makes learning independent of "space" and "time." In this way, with mobile devices today, teachers can now perform many classroom or outdoor practices that were deemed impossible to do 10 years ago. In fact, the ideas of "one or more mobile device per learner", "bring your own device", "everywhere and all the time (seamlessly)" are implemented practices rather quickly (Zhang, Looi, Seow, Chia, Wong, Chen, So, Soloway, & Norris, 2010; Wong & Looi, 2011; Song, 2014). Thus, authentic and realistic activities designed using mobile devices make it possible to reach students (e.g., Jones, Scanlon & Clough, 2013; Finkelstein, Winer, Buddle, and Ernst, 2013; Hung, Hwang, Lin, Wu, & Su, 2013; Martin, & Ertzberger, 2013; Chiang, Yang & Hwang 2014, etc.). For example, students realistically collect and explore observational data from immersive simulations (Lui, Kuhn, Acosta, Niño-Soto, Quintana, & Slotta, 2014). These tracking efforts in informal environments such as science museums, or wildlife also provoke students into developing digital literacy skills for scientific inquiry (Marty, Alemanne, Mendenhall, Maurya, Southerland, Sampson, & Schellinger, 2013). Toh, So, Seow, Chen, & Looi, (2013) propose a broad theoretical and methodological framework, including cooperative and people-centered data collection method to use mobile devices in classroom activities. They mostly focus on using tablets and mobile phones. However, using sensing technologies and other wireless tools is currently preferred in science activities. In particular, the use of sensor probes occupies a significant place in science education as, instead of only stimulating science and scientific data, they provide the direct opportunity of making real time measurements (Novak & Krajick, 2006).

In addition to above mentioned hardware tools, mobile learning activities have expanded considerably with software tools that offer system support. Web tools offer teachers and students user-generated content, usability and interoperability. As a result, teachers who used to direct their students to ready-made sources have now become able to become content providers thanks to Web 2.0. For example, web artifacts created by Web 2.0 have already been used in education for some time now (e.g., Lamb, 2007; Archambault, Tsai, & Crippen, 2011; etc.). All teachers now can create usable and interoperable environments for their students available on blogs, Facebook, Prezy dashboards and the like. As a matter of fact, even teachers accepted as being digital immigrants can very easily combine the photographs, videos, simulations of an experiment with a blog to support activities. It becomes therefore possible to use mobile devices to reach students and teachers with much more unique and learning process-focused interfaces. Crippen & Archambault (2012) discusses how, within the framework of STEM Education, science and technology classroom and out-of-classroom activities to scaffold inquiry. The research asserts that technology is in transition from desktop-based platforms to Web-based platforms and calls attention to the supports of applications. It is emphasized that these tools provide support to students and teachers, helping them to ask questions in their investigative processes, collect and explore the evidence, analyze the data and use it to generate an explanation, gather evidence, benefit from guided explanations, share, justify and defend arguments and inscriptions with classmates and teachers. These developments make it possible to transfer many simulations, videos, activities or mobile apps that would otherwise remain locally based due to differences in language, curriculums, copyrights, to a broader audience.

ISSN 1648–3898

Technology & Inquiry Based Laboratory Practices

Laboratory practices have an important role to engage students in the nature of science, scientific inquiry, and laboratory skills. To guide practices, teachers provide student lab manuals, data tables, observation sheets, equipment and supply lists, and also explanation about the use of equipment and devices. Effective use and evaluation of these tools take a lot of time and effort for teachers to continue practices, and also students to focus on learning. Technology always facilitates teachers and students' works within the recent advances. Since the 1990's, when Web 1.0 technologies were prevalent, discussions have been devoted to integrating technology into students' inquiry processes. In the beginning, technology was benefiting scholars in terms of attaining more knowledge, storing information, sharing data, communications, the visualization of data, and in analysis or modeling processes (e.g., Wallace, Soloway, Krajcik, Bos, Hoffman, Hunter,. . .Ronen, 1998; Rock, Blackwell, Miller, & Hardison, 1997; Edelson, Pea, & Gomez, 1996; Plutchak, Hall, Wojtowicz, Sridhar, Ramamurthy, & Wilhelmson, 1998; White, 1993). On the other hand, various difficulties were being reported in terms of motivation, accessibility of investigation techniques, background knowledge, management of extended activities, and the practical constraints of the learning context (Edelson, Gordon & Pea, 1999). Later, with the development of motivating investigative techniques used in the inquiry process such as probes, modeling, Web 2.0, hypermedia artifacts, hand-held computers, applications, and visualization tools, technology began to be transferred into laboratory practices much more effectively (Novak & Krajick, 2006). As well as these developments which facilitate laboratory practices, mobile learning brings new understanding of the inquiry based laboratory practices. Mobile devices, sensing technology, user-generated content, usability and interoperability support teachers in the guidance of practices. Therefore, they could guide effectively in the crowded classrooms without thinking on time-sink. As well as helping the teacher to guide practices, it is more important that they could support students' tasks to enhance their inquiry skills. Students in practices endeavor to make observations, ask questions, gather information, design, plan, and conduct investigations, analyze and interpret data, and also socially collaborate with others. Handling of all these tasks provokes them into using their process skills (Harlen, 2014). Previous researches in this sense shed some light on the use of mobile devices that might be useful for enhancing students' inquiry processes (e.g., Zhang & Quintana, 2012; Varma & Linn, 2012; Ahmed & Parsons, 2013 et al.).

In designing mobile learning for laboratory practices, how to use mobile learning for this purpose, how to plan tasks, and also how to assess the skills are important issues. Kuhn and Pease (2008) review the development of process skills in primary school. Instead of laboratory experiments, they use software-based experiments that include choosing relevant data to access, making and justifying interpretations of the evidence and relating them to their existing understandings, making predictions and other skills. They firstly organize inquiry practices at a more structured level. In time, software support diminished and was converted into a less structured level with which students could carry out their investigations independently. And also Quintana, Reiser, Davis, Krajcik, Fretz, and Duncan (2009) defined frameworks for software design that could be used to support students' learning processes. Researchers assert that the development of software should be geared to make a possible synthesis of theoretical thoughts: (1) cognitive apprenticeship (guidance from mentors through coaching, task structures and hints); (2) learning by doing; (3) social constructivism and situated cognition (socially situated tasks, social interaction and discourse dimensions); (4) accomplishing tasks within their zone of proximal development. And secondly, the authors emphasize the development of this software in the four frameworks: Design, sense making, process management, and articulation and reflection. These studies are important for using the mobile learning to design their role in the practices, but how to determine students' process skills is also an important issue. Although it is stressed that students' process skills develop early on and over a prolonged period, long-term practices and skillful activities bring students closer to using these skills (Kuhn & Pease, 2008). When it is considered that the limitations of summative test to evaluate students' process skills, the evaluation students engaging inquiry practices (i.e., doing science) could be an effective way. To determine students' during the activity, Gobert, Pedro, Raziuddin and Baker (2013) developed an evaluation method for students' performance-based process skills. Thanks to a software named Online Microworlds in the Inq-ITS (Inquiry Intelligent Tutoring System) many student skills can be pointed out in the online investigation process. The software stands out as a tool that makes it possible to evaluate process skills based on the theoretical notion of ensuring that students are "doing science", but it evaluates students in interactive simulations. Despite the limitations, the most convenient approach for assessing process skills during the laboratory practices could be direct observation of behaviors. Therefore, this research sheds light on designing inquiry based laboratory practices using mobile devices that will bring students out from the classroom setting where they are "native speakers," into an authentic, real-life situation apart from the classroom and independent of time.

Methodology of Research

General Background of Research

The research focused on the support of mobile learning in the inquiry based laboratory practices. It is predicted that using mobile devices will enhance pre-service teachers' scientific process skills during the practices. Therefore, two inquiry based practices were examined qualitatively, data gathered from two-hour practices for two weeks. The research methodology has been planned as action research to capture the status quo of mobile learning in the practices and to answer the question that how pre-service teachers' process skills were enhanced.

Sample of Research

The participants in the research were selected with the purposive sampling (or judgmental sampling) method of accessibility sampling. The practicality of working with easily accessible participants and a familiar sampling was considered in the research; the work was carried out with a student group made up of eleven (n=11) individuals. The participation was small due to the consistency of volunteer participants, and the aim of deeper considerations. The participants were five women and six men in the third-year class of the Science Teaching Department of the Faculty of Education at Western Anatolian University. The pre-service teachers were of an average socioeconomic level and comprised individuals who had been born in the period after 1980 up to the beginning of the 1990's. This age group represents the students of today defined by Prensky (2001) as the digital natives and their changing mode of learning that effectively makes use of digital media tools and technology. It was the ability of this group of pre-service teachers to use technology effectively in teaching and learning within the scope of science subjects and activities that made them the group chosen for the research.

Instrument and Procedures

The group discussions and the classroom camera recordings were used in the data collection process of the research. In the practices, pre-service teachers did activities in two groups, and the group discussions are carried out with these two groups. This allowed verifying experiment practices, the opinions and ideas. In addition to this data, to verify the data and explanations and increase validity, Google Forms' spreadsheet responses were used as data sources. Open-ended questions were prepared to be used in the group discussions. The opinions of two science education specialists were enlisted to assess the questions that were prepared. A camera recorded the entire classroom activity during the group discussions while simultaneous discussions inside the groups were recorded on the students' mobile devices. All participants were informed about recording and research procedure, and their approval was taken to have ethical clearance. And also, converting their verbal statements into a written format, each participant was coded with a number.

The implementation was carried out within the scope of an elective course that the senior pre-service teachers were taking that was called, "Entertaining and Innovative Science." The pre-service teachers were taking this course for the duration of fourteen weeks on a basis of two hours a week. The course encompassed integrated practices that included mobile devices and guided inquiry-based learning. The mobile devices consisted of notebooks, tablets, smartphones, as well as sensing probes such as conductivity and pH meters. These technologies allow students to access every kind of digital scientific data, collect and record data independent of the class. They can simultaneously receive and upload data over mobile networks and take part in many communication activities. All of these practices are important as they enrich students' learning environments in science courses and also significantly support the inquiry process that is conducted within the scope of inquiry based learning in the science classroom.

The topic "determining the quality of water" was taken up and in this context, the participants analyzed water samples in order to find their pH and conductivity properties. The pre-service teachers started off by asking the question, "Which water can we drink?" as they sought to pick out some samples of water that was drinkable. The practices were supported by a user-friendly interface, in order to guide the pre-service teachers in their experiments, and also interact with each other and the instructor; an interface was created using the Google Forms (Figure 1).

ISSN 1648-3898

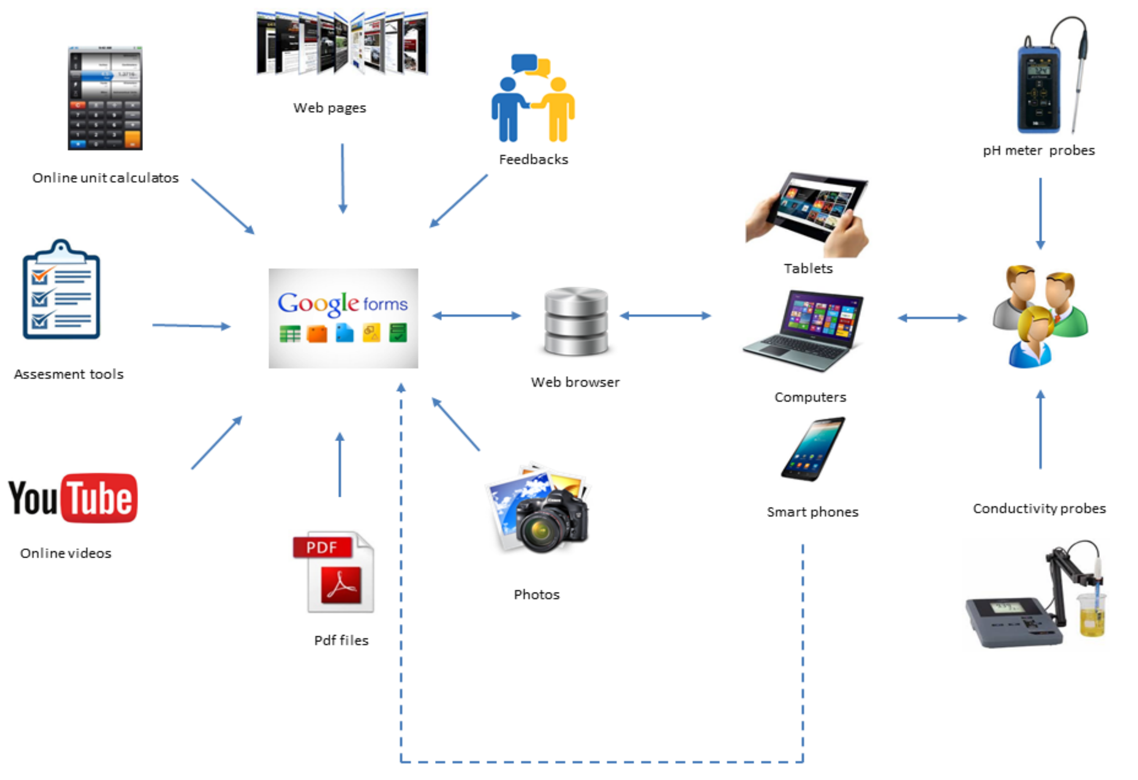
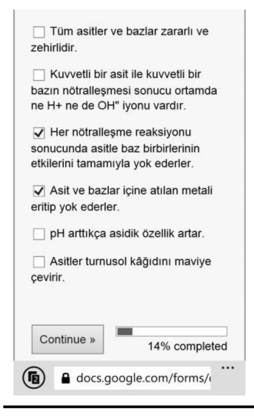


Figure 1: The interface created from the Google Forms.

Figure 1 offers a symbolic representation of the supports of the mobile devices and the way these tools interact with users. The accessibility of wireless web and mobile devices in the classroom was achieved since almost all of the students had smartphones and could use Google Forms online. Carrying these activities to an online environment makes it possible for each student to follow the activity flow individually or in a group. Thus, the pre-service teachers were able to follow up on the activity independently from the instructor and the class. A smartphone screenshots of the support of mobile devices are presented in Table 1.

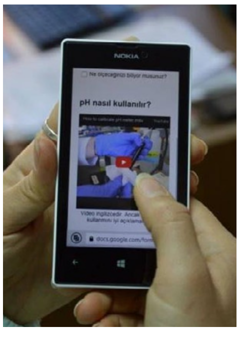
Table 1. Screenshots of the Google Forms and the flow of the activity.

Support for the eliciting of prior knowledge	
	It is important for teachers to know about students' conceptual knowledge, or previous experiences on the topic. Therefore, mobile devices can give collective information about participants' conceptual understanding. As can be seen from the screen to the side, in the first stage of the activity, the pre-service teachers responded to the items on Google Forms that they thought were right. This method makes it possible to probe into the prior knowledge of the students. A student has to answer a question before being allowed to move on to the next item. All responses are simultaneously sent to teacher's mobile device to guide inquiry.

Support for obtaining / communicating information, and planning investigations

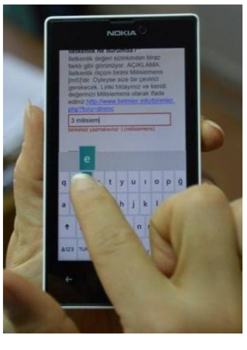
The pre-service teachers scan the web addresses given to them in the activity and write up the information they gather in a text, interpreting the data for planning investigation. By doing this, they learn about the variables that affect determining the quality of water, define the reference intervals that they will accept into the experiment, and formulate hypotheses. The information gained here is important first so that the experiments may be completed in a short while and secondly, so that it is completed in line with its goals. As can be seen from the smartphone screenshot image to the side, each of the student's statements written into the Google Forms from the smartphone is evaluated during and after the activity and the student is provided with feedback.

Support for carrying out investigations



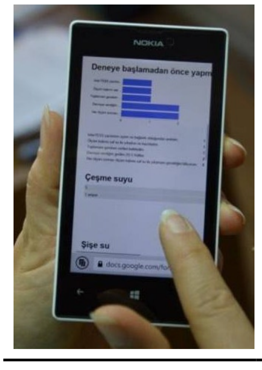
The pre-service teacher in the photograph is learning what the sensor probes are that they will be using in the experiments with video and other multimedia plug-ins, what sensor probes are, how they are calibrated and used. Thus, the student is able to repeat the subject and images as much as desired, independent of the instructor.

Support for analyzing and interpreting data, using mathematics and computational skills.



In the photograph, the pre-service teacher is converting the data collected via sensor probes into other unit systems using online unit conversion applications (using Volt, Ampere and Centimeter values to convert into Millisiemens), after which this is recorded in a report. When a unit is not defined, the instructor may receive feedback on the basis of a report of the data in the unit system that the instructor had previously added onto the Google forms. Thus, the student gains knowledge and also skills as to how to report measurements accurately and in a manner that is in line with the nature of measuring.

Support for engaging in argument from evidence, evaluating / communicating investigational results.



In the responses of Google Form, spreadsheets make it possible within the process to share all that is written with the groups simultaneously after the activity. After completed the activities, they can see what their peers verbalize, what they found as a result. This offers the entire class the chance to discuss and evaluate the activity as a whole.

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Data Analysis

Mobile learning and their supporting inquiry based laboratory practices were investigated in the research using group discussions, classroom video records and Google Form spreadsheet responses. The data were analyzed with directed content analysis. Based on the work of Martin, Jean-Sigur, and Schmidt (2005), the initial coding scheme determined prior to beginning to the analysis of data. They discuss the assessment of process skills as divided under two fundamental themes (basic and integrated process), and each theme has sub-themes (Table 2).

Table 2. Coding themes to science process skills.

Theme	Basic Process	Integrated Process
Sub-themes	Observing	Identifying and Controlling Variables
	Classifying	Formulating Hypotheses
	Communicating	Interpreting Data
	Measuring	Defining Operationally
	Predicting	Experimenting
	Inferring	Constructing Models

The research analyzes process skills in each sub-theme with proficiency indicators. These indicators are used as the coding scheme of this research. For example, under the sub-theme of observing are the codes (1) identifies objects, (2) uses more than one sense, (3) uses all appropriate senses, (4) describes properties accurately, (5) describes changes in objects, (6) provides qualitative observations, (7) provides quantitative observations. All of the data were analyzed independently by two separate researchers who used the Nvivo 8 program. The investigators calculated Cramér's V to determine the accord between the researchers. Cramér's V was found to be .79. A value of between .70 *- .100 indicates a strong correlation between the analyses of the researchers (Cramér, 1999). The statements that did not reveal concordance between the codes were re-evaluated by the researchers.

Results of Research

Based on the data from group discussions (GD), camera recordings (CR) and Google Forms' spreadsheet responses (SR) of the preservice elementary teachers, the support of mobile devices in doing two laboratory practices was analyzed. Their verbal statements, and behaviors converted into a written format, and each participant was coded with a specific number (*Student 6-G.D.* - statement comes from group discussion). The two activities emphasize the solution of much-debated daily issue – determining the quality of drinking water. Both of them have the unique analysis techniques, which they are relatively difficult to complete without guidance. And also pre-service teachers were not familiar with that kind of practices, but they were not reluctant to the practices. They completed both of the activities at the same time, and they also determined one bottle as drinkable water according to their experiments.

Process Skills of Students Used

The practices contain a broad coverage of the process skills observed to have been used by the pre-service teachers (basic and integrated process skills). While some of the skills were directly associated with the experimental or laboratory practices, some of them were supported by mobile learning. For this reason, the data analyzed firstly based on codes determining which skills come to the fore. The model obtained with the NVivo 8 qualitative analysis program to show actual states of the process skills in the practices is presented in Figure 2.

In the model presented below, the level of use of skills is specific to these practices and it is seen that some skills are used in more concentrated fashion. Showing or expressing of every piece of skills in behavior is limited, but determining the overall state of skills gives an idea about the practices. As indicated in Figure 2, identified skills come from different sources (S) and different references (Ref.). In the analyses, same of the references indicate more than one skill, so same reference sentence used for each skill. Another issue is that when the same skill comes from different sources, the most obvious one was preferred for coding. Actually, pre-service teachers used mainly measuring, observing, identifying and controlling variables, interpreting data, classifying, and experimenting skills. The unexpected result does not exist for students in that laboratory practice. Because both activities are organized in the structured way of understanding and guided strictly, and the points guided by mobile devices are associated with the outstanding skills in the model.

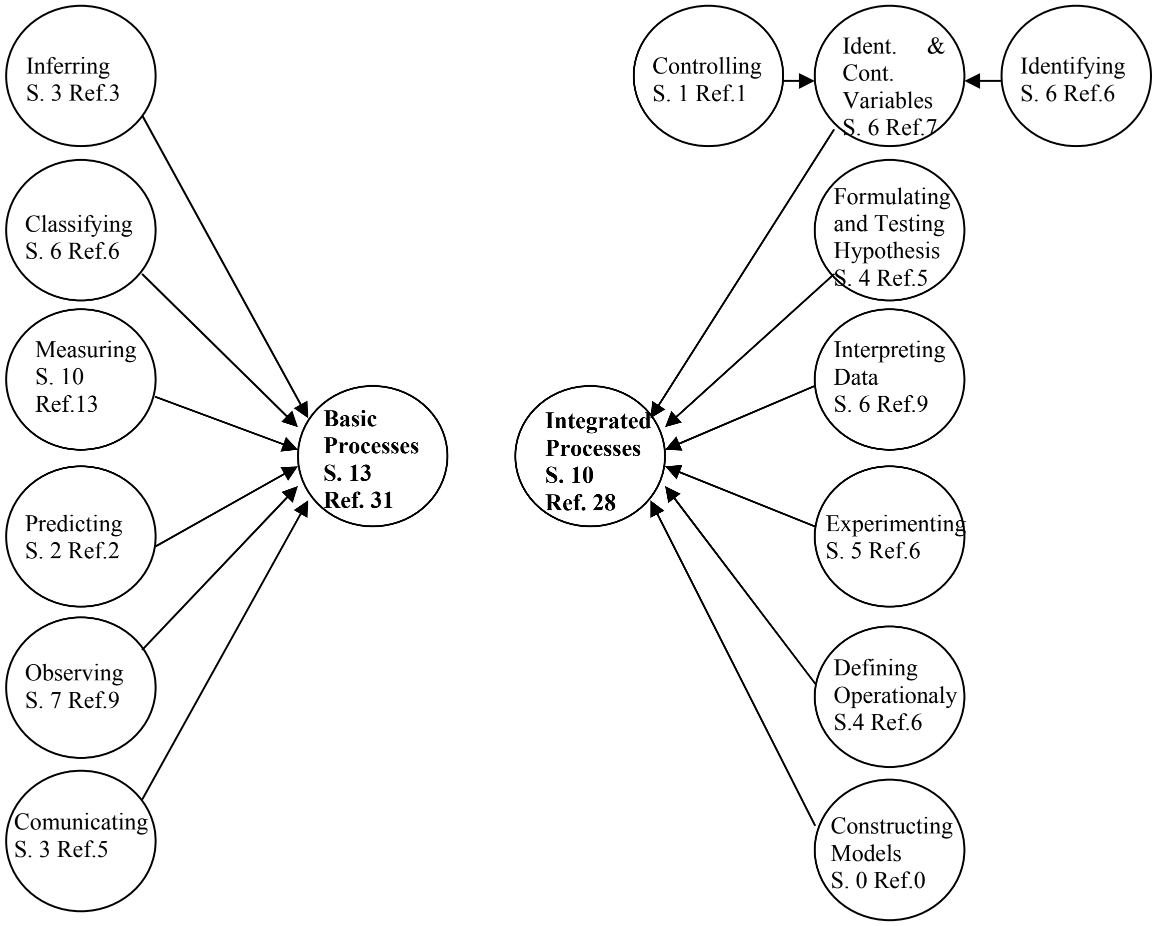

Figure 2: Shows the level of use of the process skills determined in the data.

Process Skills Which Were Enhanced By the Use of Technology

The research point out the potential support of mobile devices in the inquiry based laboratory practices. To assert that, it would be useful to identify the contributions of those within the scope of mobile learning to enhance science process skills. Some of the practices supported mostly with mobile devices are explained in Table 1. They both guide pre-service teachers to simplify their works, and are also used as the experiment equipment. In the practices, mobile devices as the experiment equipment made it possible for the pre-service teachers to broad their observational area and use these skills. pH and conductivity sensor probes are mobile devices to observe waters compound deeply. The role of mobile devices is that creating an environment conducive to observation was created to facilitate the pre-service teachers' answering the question "Which water can we drink?". In Table 3 shows sample responses about the support of mobile devices that they make some characteristics of waters observable.

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Table 3. The support of mobile devices to enhance observation.

Source	Reference	Codes
Student 6-G.D	I looked at the values written on the bottled water that I look at and drink every day for the first time.[1] This was the first time I was trying to explain something that I didn't know anything about... Because the results were concrete[2], I can say the measured[3] values were quite reliable...	[1]Identifies objects [2]Describes properties accurately [3]Provides quantitative observations
Student 5 - C.R.	For a week now, I've been looking at the conductivity property of the water that I drink every day, which I had never looked at before. The water comes from different sources and has different tastes[1] but they're all the same *(the value shown on the label)*; I think they've all printed the label without analyzing it...[2] (italics added)	[1]Uses more than one sense [2]Describes changes in objects
Student 5 - C.R.	The student got up from his place to see whether the result he arrived at conformed to the real value on the bottle; he looked at the label to see whether the conductivity values written on the bottle were the same as his own results…	Provides quantitative observations

The ideas expressed that they are able to use technology to make objects that cannot be perceived by the senses become observable. The phenomenon here that is the object of the observation was the water he drank every day, a phenomenon right out of his own daily life. Although, the system support provided over mobile devices does not directly guide the participants in using classifying skills, they helped for the instructor to know how each one classify the waters as more drinkable and less drinkable both at the beginning and at the end of the practices. Some sample responses are shown in Table 4.

Table 4. The data on classification skills.

Source	Reference	Codes
Student 3 - G.D.	Actually there are more ions in drinking water than in pure water. But mineral water has even more ions than water.[1] That's why we think that mineral water is more drinkable.[2]	[1]Identifies major properties by which objects can be sorted [2]Establishes own sorting criteria
Student 5 - C.R.	According to this, because mineral water has the highest number of ions, or has the most ions[1], its electrical conductivity is greater and that's why we should drink mineral water.[2] Let's first measure pure water, then bottled and mineral water *(puts them in a row on the table)*… (italics added)	[1]Identifies major properties by which objects can be sorted [2]Establishes own sorting criteria

Mobile devices introduce many innovations in enhancing process skills, especially communicating skills. The use of the wireless internet completely opened the doors of the classroom to the scientific knowledge. In addition to allowing the participants to access scientific information over the Internet, the transfer of their ideas to the outside world was also achieved. In particular, the reported statements of the pre-service teachers on the spreadsheet indicated that the classroom applications had made it possible for them to access information and effectively transmit this information to their peers. A related sample spreadsheet response is shown in Table 5.

Table 5. Spreadsheet response on communication skills.

Source	Reference	Codes
S.R.	This is 5.5 - 8.5 in drinking water *(scientific pH rates of drinking water)*.[1] This information is from the Ministry (X) project. We believe that this is a reliable piece of information because it was obtained from a research by experts in a laboratory setting. (italics added, and X – removed name)	[1]Formulates reasonable and logical arguments to justify explanations and conclusions

Mainly, looking at the answers on the Google Forms spreadsheets during the practices provided the instructor and participants with an opportunity for articulation and reflection on the lesson. For example, at the beginning of the pH practices, three participants thought that acids burn and fuse everything, two of them thought that all acids are harmful and poisoned, and two of them thought that when the pH level increases, acidic level is increased. These are well-known misconceptions in chemistry, and easily determined at the beginning of the practices. It would be almost impossible for the learner and teacher to access anonymously other thoughts in such a short time in the environment where there is no technology.

The conductivity and pH meter sensing probes used in the practices encourage students to employ evidence-based inquiry. The technologies can turn an ordinary classroom into a laboratory. The pre-service teachers were able to work with the mobile devices to carry out an analysis of conductivity and pH that would not be possible without technology. In fact, that the student could arrive at the values specified on the label of a purchased bottle of water was an important source of motivation. Some data on measuring skills and the support of mobile devices are shown in Table 6.

Table 6. Reference data on measurement skills and the support of mobile device.

Source	Reference	Codes
Student 5 - G.D.	At first it was as if the values were being calculated with more sophisticated instruments but the instrument is really very simple and it's doable *(analyses-measurements)*. (Italics added)	Applies measurement techniques appropriately,
S.R.	The conductivity of drinking water must be between 50-1500 mS. We measured it to be 588.3 mS[1], the value the company gives is 188.1 mS. When the bottle gets into contact with the air, the water gets dirty and its conductivity increases. We obtained a very different result from what we measured. We should drink bottled water because there is a huge difference between the value they give and the value we found *(They found correct value, but they forgot the distance between plates)*.[2] (Italics added)	[1]Uses measurements as evidence, uses measurements to help explain conclusions [2]Uses measurement instruments properly
S.R.	We used the pH meter for the first time. We learned what the range of the pH for water was. We can look for the pH value in the other beverages we drink in our daily life to see whether they're healthy. The use of the pH meter [1] and measuring the pH value were topics we had had no experience with before. We can now look to see at what intervals the drinking water on the market is checked and how reliable the pH value is.	[1]Applies measurement techniques appropriately,

In the applications, the YouTube videos added to the Google Forms were used to guide the pre-service teachers in appropriately using the mobile sensing probes and honing their skills in learning about the technical information specific to a measuring device, appropriately expressing the measurement digitally in suitable units and learning reporting techniques. It can be seen that the pre-service teachers, in keeping with the nature of measuring, compared an unknown magnitude (conductivity) with a known magnitude (voltage, current and distance), used the units correctly and successfully tried to report the results of the measurements. Even though when writing down their statements, they read the results of the measurements correctly, they made a mistake in calculating the value of the surface of the water but this calculation error was realized in the discussions. The system support allowed the instructor observing their all practice process, therefore the instructor easily determined where they made a mistake. In addition, it was seen that the pre-service teachers were able to convert the units measured using the unit conversion apps added to the Google Forms and to produce an acceptable report.

In the practices, the pre-service teachers frequently remarked that they were working and feeling like scientists. Beyond basic skills, the scientific knowledge they generated necessitated the use of higher order skills. Using mobile devices provoke them into the reaching all variables to design their experiments and test their predictions. Without using technology, it is not possible that the participants identify all variables (temperature, color, mistiness, smell, electrical conductivity, pH value, taste, hardness analysis, fluorine analysis, and the salt) and also their reference rates to test waters. Therefore, mobile devices support them in identifying and controlling variables. Some reference ideas related to these skills are shown in Table 7.

Table 7. The roles of mobile devices on identifying and controlling variables in the practices.

Source	Reference response	Codes
Student 7 - C.R.	Found the criteria for determining water quality from among the pdf files[1], told the group that these criteria were related to their question and asked them: "To what degree of color is water still drinkable?" This question implied that color too was a variable.	[1]Identifies factors that might affect the outcome of an experiment

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Source	Reference response	Codes
Student 5 - G.D.	In the beginning, we determined the variables that indicate whether water is drinkable or not--factors such as the clarity of the water, its temperature, color, mistiness, smell, electrical conductivity, pH value, taste, hardness analysis, fluorine analysis, the salt content.	Identifies factors that might affect the outcome of an experiment

Mobile devices gave instructor a feedback about participants' predictions and how they formulate experiment hypothesis in the practices. Thanks to mobile devices, determining all the variables related to the quality of the water was helpful to them in formulating their hypotheses. Sample references about this skill reported by mobile devices, and ideas from group discussion are shown in Table 8.

Table 8. Ideas on how the hypothesis formulated in the practices.

Source	Reference response	Codes
S.R.	Electrical conductivity and the water quality are directly proportionate; pure water won't conduct electricity because it has no dissolved minerals and so that's why mineral water is the highest quality.	Constructs a hypothesis when given a problem or question
Student 3 - G.D	I knew that pure water did not conduct electricity and I knew that fountain water contained dissolved minerals but I didn't know how far I could go with this. I couldn't decide whether it would be good if they were dissolved or how much they should be dissolved.[1] I thought that the relationship would be proportionate so I started to test it. First I decided which one would be more suitable for drinking and determined which one I should choose; then we tested it[2].	[1]Suggests several plausible hypotheses to explain observed situations [2]Develops ways of testing hypotheses

The pre-service teachers were considerably successful in using mobile devices to interpret the data. They systematically reported their findings during the tests, and tried the measurement again and again in a short time. This gave them persuasive results, and they also found reliable sources to interpret these results. It was seen that the students set forth their reasons and references in the Google Forms and interpreted the results. Some references on how they interpret their experimental results are shown in Table 9.

Table 9. Pre-service teachers' interpretations of data to determine water quality.

Source	Reference	Codes
Student 1 - G.D.	I wasn't waiting for a result like this. There was a big difference between what was written on the water label and what we measured, but in the end, the water turned out to be in the range of being drinkable.	Collects data that is useable as evidence
S.R.	We think that No. 3 is drinkable; the acidic value of the first and second water is higher[1] and therefore they are not drinkable.	[1]Collects data that is useable as evidence
S.R.	Because the water in the first bottle is too acidic, it would be harmful for our bodies and it would reduce the pH in the environment. Even though the second bottle is close to the ideal, it is still more alkaline than ideal water. Because the third bottle is considerably alkaline, it would increase the pH of the environment and the balance would be broken again. The water that is closest to the ideal is bottle No. 2 and so it is the most drinkable water, but its pH is not very reliable on the other hand.[1]	[1]Makes valid interpretations of data

As shown in the images in Table 1, they can write their ideas as an open-ended in a paragraph by mobile devices. These parts of the system supported their definitional skills. In Table 10, it is seen that they displayed these skills in their concluding paragraphs. They are beyond interpretation and related to what they observed, how they expressed what was measured and their thinking processes in doing this in terms of making a comparison with present scientific knowledge:

Table 10. Sample paragraphs from spreadsheet responses about the skills of defining operationally.

Source	Reference response	Codes
S.R.	Based on our data, we believe that drinking mineral water is better. This is because mineral water is rich in dissolved minerals and based on the theoretical knowledge that pure water is not a conductor of electricity, we decided on mineral water. There are no dissolved ions in pure water and so from this perspective, mineral water is better.	Verbalizes congruence between operational definition and the variable to be measured
S.R.	The conductivity of drinking water should be 50-1500 mS. The value we measured was 588.3 mS. The value the company gives is 188.1 mS; we arrived at a result that is very different from what we measured. It could be because the water is in a plastic container or otherwise, we might have made a mistake in measuring.	Verbalizes congruence between operational definition and the variable to be measured

Discussion

In this research, supports of mobile devices for students' inquiry process are discussed with two laboratory practices. Without any support with technology, doing above mentioned activities are quite complicated with pre-service teachers. In practices, supports can be given by a variety of sources – by teacher, by curriculum materials, by technology, and by peers (Krajcik, Blumenfeld, Marx, & Soloway, 2000). The mobile devices used in practices largely support inquiry. According to the findings, the pre-service teachers were at first inexperienced during the practices in terms of background knowledge (water quality criteria, conductivity and pH value criteria, etc.) and skills (using measuring tools, mobile devices, etc.). In previous studies where inquiry had been integrated with technology, it was reported that students could have difficulties related to background knowledge and the accessibility of investigation techniques (Edelson, Gordon & Pea, 1999). In the present research, by accessing the scientific information on water quality via Google Forms, they were able to overcome these handicaps. They used the same platform to watch YouTube videos and photographs to learn about conductivity and the use of pH meter measuring tools as they employed conversion systems and units they had never had experience with before. The current Next Generation Science Standards (NGSS) uses the word "practices" in place of "skills" and underlines that each application that students will be asked to work on will require its own unique set of knowledge and skills (NRC, 2015). In this sense, with these types of applications, it is of the greatest importance that the support provided to students in the way of knowledge and skills is integrated with the particular subject matter. In this context, many Web 2.0 tools such as social networks, photos, search engines, visualizations play an important role in integrating via mobile devices on the single interface of Google forms. Crippen & Archambault (2012) stress that in STEM applications, besides gaining process skills, students must be given the skills to use the web. When the instructor makes use of these technologies in applications, the learning environment is integrated through the many digital tools that are brought together to help teach the subject at hand. Also, considering the time that it would take for students to access these instruments one by one on the digital medium, it is clearly evident how time-effective these applications are. According to Presky (2001), the students of today who are digital natives prefer parallel processes, multitasking, reaching information rapidly, reading visually rather than in writing and do not take pleasure out of slow-moving, step-by-step, "one thing at a time", individual technology. In the applications, the pre-service teachers worked in full cooperation, with one of them searching the Internet for scientific information, another making predictions about the subject, and still another writing these thoughts down in Google Forms via mobile devices. Thus, a lot of work was completed in a very short time, all for a single common goal.

The results of the research contain a broad coverage of the process skills observed to have been used by the pre-service teachers (basic and integrated process skills). There are two main reasons for this. The first reason is to be able to determine how much the application carried out by the pre-service teachers was in conformity with the nature of inquiry. That the pre-service teachers used scientific processes in their applications indicates that they were in the process of generating scientific ideas and engaged in the process of inquiry (Martin, Jean-Sigur, & Schmidt, 2005). Process skills develop in students at early ages and within a determined time frame. Once these skills are attained, however, they can be used whenever the need arises. For this reason, in this research carried out with pre-service teachers, the focus was not on their developing the necessary skills but rather on the extent of what these skills encompassed. Secondly, to better understand the enhancement of these process skills, it would be useful to identify the contribution of Google Forms to these skills and to mobile devices by offering interface support. The unexpected result does not exist for students' inquiry practices. In previous studies, mobile devices

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were used as a tool support carrying out investigation, using mathematic and computational thinking, and obtaining, evaluating, communicating information (Wilson, Goodman, Bradbury, & Gross, 2013). While the pre-service teachers used their mobile devices in the applications, they used the conductivity and pH meter sensor probes in their measuring. Using the sensor probes and the user-friendly interfaces allowed the pre-service teachers to carry out two applications that they would not have been able to do without this available technology, all in the space of a short class hour. In this process, the pre-service teachers obtained simultaneous and real data and were able to record it in the system digitally using the appropriate units. In both applications, mobile devices simplified (not easier) the subject, a factor that is many times neglected in inquiry. Thanks to these tools, the pre-service teachers performed the same measuring operations that scientists do, following the same investigatory process, succeeding in using their skill to access information, make predictions and explain and reach a successful inquiry, in other words, arriving at the level of testing, comparing and interpreting, all in the space of one short class hour. Being able to complete the measuring and interpretation processes in such a short time, encouraged discussion and new investigation. As a matter of fact, NGSS recommends that classroom applications reach beyond inquiry to a higher dimension, that is, the dimension of designing for engineering (NRC 2015).

On the other hand, the Google Forms that provide interface support for mobile devices, as well as the question items, offer students an integrated environment of both content knowledge and process skills. Using this type of interface in an activity offers teachers and students user-generate content, usability and interoperability. This way, individuals distancing themselves from technology due to language problems, curriculum differences, the instructor's approach to inquiry no longer pose problems. For example, prior to each activity, the students were asked a few questions in their own language about certain misconceptions. Using these applications at the beginning of class is invaluable for a teacher who would like to evaluate the background knowledge of the students. Although the applications contained no information about conductivity or the use of pH probes, the support given by the system helped the students shorten their data collection times and provided them with rapid access to the information, thus giving them more time to interpret and evaluate. Because the applications necessitate a great many tasks, this stimulates conversations among group members, encourages them to look at data critically and collaboratively and revise their questions to be more comprehensive.

The field literature emphasizes the need to support students with technology to help them with articulation and reflection (Quintana, Reiser, Davis, Krajcik, Fretz, & Duncan, 2009). Combining digital content with Google Forms allowed the ideas of pre-service teachers to be recorded on the digital medium after the applications. When students' ideas are recorded on the digital medium in this way, all of the students are able to see all the ideas simultaneously at the end of the activity. Thus, a great many arguments and graphs appear on which to stage a discussion and evaluation. In this process, when the instructor makes a general evaluation, this makes it possible for the pre-service teachers to review the results and rethink the entire investigation. The general misconceptions, joint ideas in the classroom, the consistency of the results, the evaluation of different ideas about the activity after it is over, reach the instructor as feedback as to what has been learned and the process skills that were used in the learning. This application at the same time largely supports the approach of evaluation through "doing science" using process skills (Gobert, Sao Pedro, Raziuddin, & Baker, 2013).

Another purpose of focusing on process skills is to understand how much the technological integration is in line with the theoretical ideas portrayed in the literature. The term "scaffolding" has been frequently used to express the support given to the technology-based inquiry process (e.g., Crippen & Archambault, (2012); Raes, Schellens, De Wever, Vanderhoven, (2012); Kim & Hannafin, (2011), et alia). One of the scaffolding headings determined by Quintana et alia (2009) support students in the form of skills (e.g., generating hypotheses, designing comparisons, collecting observations, analyzing data, and constructing interpretations, etc.). For this reason, in our applications, the pre-service teachers used mobile devices (tablets, smartphones, sensor probes) to support their process skills in the topics of ion amounts and degree of acidity.

When the practices are considered in terms of inquiry, these technologies act as an additional and secondary guide to promote inquiry. This signals the level of practices that is called guided inquiry in the literature. In the research, it was observed that the pre-service teachers were unable to rise to the constructing model's process skill. In this sense, the level of support provided by technology should be well planned. Similar situations can be seen in other applications on process skills in the literature as well. In general, rather than becoming more structured, applications are gradually reducing the software support and converting these forms into less structured materials which students can use to carry out their investigations independently (Kuhn & Pease, 2008). Although the applications did not rise to the open inquiry level, it was seen that the pre-service teachers were successful in doing many things under the guidance of technology that they would not have been able to do alone or led by the teacher. Lastly, it must clearly be stated that adapting technology to the classroom not only facilitates the work of the instructor but is also a requirement. Although the focus of this research was the process skills of the pre-service teachers, it must be said that it would have been hard to reach the desired goal with these applications if it had not been for the serious support, level of knowledge and experience of the instructor in the system preparation stage.

Conclusions

This research discussed the support of mobile learning into two inquiry based laboratory practices. In both activities, the practices supported via Google Spreadsheets, mobile devices, and sensor probes. The main attention of the research was how to enhance science process skills with these tools. That the pre-service teachers used scientific processes in their laboratory practices indicates that they were in the process of generating scientific ideas and engaging in the process of inquiry. This is an important role of the laboratory practices indicated in pre-service teacher education curriculums. It was seen in the overall analysis of process skills that the pre-service teachers successfully employed their skills of observing, measuring, identifying variables and interpreting data.

The technology used in the practices and the support given in terms of knowledge and skills were integrated with the topic. The topic and the practices became more meaningful for the pre-service teachers because of the association made with their daily living, the things they were curious about and because it was an activity that arose out of their own needs. This could be also stem from their expectations from science teacher education. The practices also responded to the learning processes and expectations of today's digital natives, the pre-service teachers, going beyond the classic classroom lesson or laboratory practice. In practices, besides simplifying the students' experiment process, the support of the mobile devices and interface also simplified the procedure itself. Thus, while doing science, they did get lost in a set of comprehensive experimental processes. Google Form Spreadsheets add-on mobile devices and question items offered interface support and provided the students with an integrated environment. Their simultaneous and real-time measuring with sensor probes support gave their experience in learning about measuring instruments and techniques, expressing measurements digitally with appropriate units using reporting techniques. And also, the use of mobile devices acts as a secondary additional guidance to the practices. They were able to complete the practices in the short span of a classroom hour, something they could not have done without the technology. Recording their ideas in the digital medium gives the instructor and the students the opportunity to carry out simultaneous articulation and reflection on their misconceptions, common ideas, the consistency of their measuring results, and their learning about the different ideas set forth in the activity.

Further Implications

For further researches, it is planned that more informal non-classroom approaches will be integrated with different subjects. In-service teachers will play a major role in ensuring that these types of practices are made more widespread. In particular, in-service teachers who have an affinity for technology, it is planned, will be training instructors in the use of these technologies.

The fact that the pre-service teachers were unable to rise to the level of constructing models in the activities that were prepared encourages us to focus in later studies on incorporating mobile devices into applications. The pre-service teachers were predominantly focused on the investigation processes in the activities and they were not expected to create an artifact but it is believed that in more advanced studies, web tools can be used to portray their understanding. Thus, by making use of texts, digital pictures, movies, graphs and other tools, students may be encouraged to articulate and reflect more in the learning process.

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Received: *March 21, 2016* Accepted: *April 27, 2016*

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