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SIGNALING PRINCIPLES IN INTERACTIVE LEARNING MEDIA THROUGH EXPERT'S WALKTHROUGH

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ABSTRACT

This study studies the impact of signaling principles upon interactive learning media. Normally designers just design and develop learning media for use in schools without considering the way it eases user tasks. Bearing in mind that signaling users while learning with interactive learning media is important, this study incorporates signaling principles while designing it. Thus, this paper aims to discuss the appropriate signaling principles for learning media from experts' perspective. Iterative Triangulation Methodology has been gone through in achieving the aim. Altogether, activities in three phases have been carried out; requirement analysis, design and development of the prototype, and expert evaluation using a walkthrough. Results reveal that although the prototype has been designed by involving users; in terms the incorporation of signaling principles; experts still discover a number of excise as a result of not applying signaling principles.

Keywords: Signaling, principles, interactive, application

INTRODUCTION

Multimedia has been used in improving the quality of teaching and learning process (Munadi, 2013). It makes learning contents more attractive, easily understood, more varied, and it could also provide more learning activities (Mayer 2017), which implies in its design (Aziz, Mutalib, & Sarif, 2015). When properly designed, multimedia learning could present abstract concept into concrete; bring the phenomenon of dangerous, rare or difficult to obtain to be presented into the class; present extremely fast-moving object in a slow representation; allow students to interact directly with the environment; allow uniformity of observations and perceptions for student learning experience; generate motivation to learn; present learning information consistently and can be repeated or stored according to need; and present the message or learning information simultaneously. In fact, Mayer (2017) goes beyond that, that it supports various tasks that enable learning takes place in a virtual environment. It is in-line with the request of the fourth industrial revolution (4IR), which underlines that the use of technology absorbed into daily life, including education. As it has taken place, every society has to be ready for facing it (Ward, 2016).

As a response to such advantageous, various works have been carried out for the purpose of enriching the learning experience. As an example, Dolhalit, Salam, Mutalib, and Yusoff (2017) embed persuasive principle in their multimedia learning in promoting awareness on truancy disadvantageous among school students. Meanwhile, Elkabani and Zantout (2015) and Aziz, Mutalib, and Sarif (2017) apply simplicity principle in their multimedia learning for visually-impaired learners in schools, while Tosho, Mutalib, and Abdul-Salam (2016) designed a multimedia learning for inclusive users. Also, Walsh, Petrie, and Odutola (2014) use multimedia in teaching about culture. Nevertheless, it has also been used in teaching practical skills (Baharuddin & Dalle, 2017) and for use in extremely-crowded situations (Al-Aidaroos & Mutalib, 2015). Those are part of initiatives that prepare the society for facing the learning paradigm in the 4IR (Baygin, Yetis, & Karakose, 2016; Li, Hou, & Wu, 2017). One challenge in dealing with the 4IR is the ability to design for solutions creatively (Carter, 2017).

Although learning is generally understood, Gardner expresses eight different types of intelligence through his Multiple Intelligence (Gardner, 1983; Gardner, 1993). One of them is visual intelligence, which argues that there are people who learn best through visual representation. In response to that, this study believes that multimedia learning will benefit students in their learning process (Tomita, 2017). It is especially applicable for topics that contain processes, especially those involving materials difficult to get, including learning physics.

'Physics' originates from Greek, namely physics which means "natural". Physics is part of science that studies the relevance of physics concepts with real life. According to Chiapetta and Koballa (2006), physics consists of 4 dimensions: (1) way of thinking; (2) ways to investigate; (3) knowledge; and (4) its interaction with technology and society. Many works have been carried in supporting the teaching and learning of physics. Regarding this, Doyan and Sukmantara (2014) developed an intranet for the physic course. They used the intranet to increase learners' various skills. Similarly, Stankova, Barmasov, Dyachenko, Bukina, Barmasova, and Yakovleva (2016) studied the efficiency of computer technology in learning physics. In fact, Toenders, De Putter-Smits, Sanders, and Den Brok (2017) have worked with visually-impaired learners to solve their problems. Those studies focus mainly on providing contents in digital form, with various media representatives. Besides physics, other works in science stream have also been developed. Obviously, Aksoy (2012) used animation in teaching 7th-grade science and technology course. More advanced than that, Chiang, Yang, and Hwang (2014) used augmented reality. In terms of class operation, Fautch (2015) used flipped classroom to enable learners to learn more actively.

Discussions in the previous paragraphs demonstrate the power of multimedia in supporting the learning process. However, ensuring learners are happy using the multimedia learning is another issue. Accordingly, this study attempts to design a web-based learning media (as carried out by Butcher (2006)) for physics for use in schools in Indonesia. For the purpose of this study, static fluid is selected. It has been decided after observing the practical operation in schools. Through the observation, it was found that laboratories are abandoned, but topics are delivered through conventional lectures. It is because laboratories have limited tools for experiments, besides the inability of the laboratories to support a large number of students. As a result, learners feel bored learning physic topics. Those topics could be best learned through experiencing them, for the learners to visualize the processes and their effects. However, cost really matters in making all tools available. Thus, an alternative solution could be attempted. This could be overcome through the use of media technology, as have been carried out by the previous researchers discussed in the previous paragraphs.

Designing and developing the interactive learning media must be tailored for the intended users, and appropriate for the context of use; who are school learners in Indonesia. Otherwise, it will not be successfully achieving its goals in its desired context. The concern of this study is on learning experience, as recommended by Cooper, Reimann, Cronin, and Noessel (2014). Users tend to get frustrated when they experience difficulties in utilizing the learning materials (Preece, Sharp, & Rogers, 2015), hence they do not engage their attention with the learning activities and the learning contents. According to Sweller, Ayres, and Kalyuga (2011), eliminated excise and reduced cognitive load are among factors that could increase user engagement in using interactive learning material. Among the famous ways to ensure that is by considering certain principles in designing the product (Clark, 2014). In response to that, this study decides to apply signaling principles in designing the web-based interactive learning media, as recommended by Mayer (2014) and Mautone and Mayer (2001). It is one of the principles in multimedia learning (Butcher, 2014). It has to go through a scientific and systematic process (Mayer, 2009; Mayer 2011). In accordance, this paper aims to demonstrate the expert review of the developed web-based learning media.

This section discusses the background of this study, including the problem to be solved. The aim of this paper is also stated. Next, an explanation of the research procedure follows. Then, the results and findings follow. Finally, this paper ends with a discussion on the impact of this study on the context.

METHOD

This study involved three parts; requirement analysis, development, and evaluation; which require iterations of processes. In fact, there are a number of iterated data sources and methods. To fit these requirements, this research adopts the triangulation research method. In regards to that, Iterative Triangulation Methodology has been adapted. The triangulated data source and methods are visualized in Figure 1. Triangulation is applied in terms of data source, method, theory, and data analysis.

- Data source triangulation – this study gathers data from a different time, space, and persons. This increases the possibility of revealing a typical data or the potential of identifying similar patterns, thus increasing the confidence of the findings.
- Methodologic triangulation – could also be called mix-method or multi-method, and can be seen in both data collection method and research method. Use of different methods provides richer information to the study.

Further, Figure 2 visualizes the steps carried out throughout the research work mapped with the deliverables.

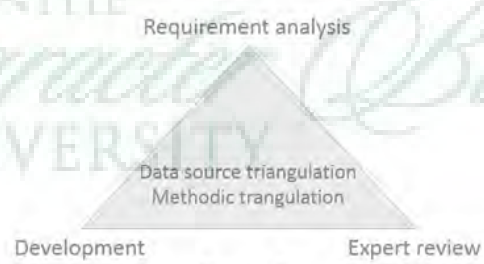


Figure 1:
Triangulation methodology

Figure 2:
Research methodology

Figure 2 shows that the requirements were gathered through observation and analysis. Upon commencement of this study, having understood the problem, as discussed in the Introduction section, this study observed the teaching and learning in the classroom. It was found that teachers teach in a conventional way, and learners do not participate. It is totally book-based, and learners show no excitement. After a few sessions of observation, this study interviewed the teachers. The interviews were held in schools, where they teach. The aim of the interview was to gather their view on the use of visual representation (multimedia learning application) in their teaching and learning on top of the book. Also, it was aimed to gather additional input if they are happy with the multimedia learning application.

Obviously, the teachers accept the idea of utilizing multimedia learning application for their classroom teaching. In further discussion, the teachers agreed to select static fluid as a start. Particularly, they emphasized that Pascal law, submarine, regional water company, and principal of Archimedes are topics must be made available. It was decided on reasons that the topic is hardly explained without a visual representation, especially because it requires special setting and tools. When it could be visualized using multimedia learning application, it could better support their teaching and learners' understanding.

Having interviewed the teachers, this study interviewed the learners, to gather their requirement in the way they expect the application to support their learning. The interviews were also held in schools, where they study. Based on their feedback, they prefer a web-based application so that they could access the learning content anytime anywhere. They have no idea about the applications' look and feel, but they just need an application that is friendly to them.

Based on the results of the observation and interview, this study could deduce that the requirement is clear, that users need an interactive learning media that provides contents on static liquid (particularly on Pascal law, submarine, regional water company, and principal of Archimedes) for them to access any time anywhere. For this study, the content on the static liquid is taken from the textbook, while the focus is to make the learning media usable for the users. Particularly, the learning media should minimize users' cognitive load by minimizing excise.

Based on the requirements, the look and feel of the prototype were designed. Ideas were put on a storyboard (the sample is available in Figure 3). It was used for gathering feedback from the users; teachers and students.

Figure 3:
Sample of the storyboard

The storyboard was presented to users in a cyclical process, for them to give their comments and feedback on the design. The sample in Figure 3 is the finalized design, in which they prefer an application with windowing and menu interaction style.

Then, the design was transferred into a working prototype. Flash CS5 was used in making animated representations. Figures 4 through 7 depicts some of the snapshots of the learning media.

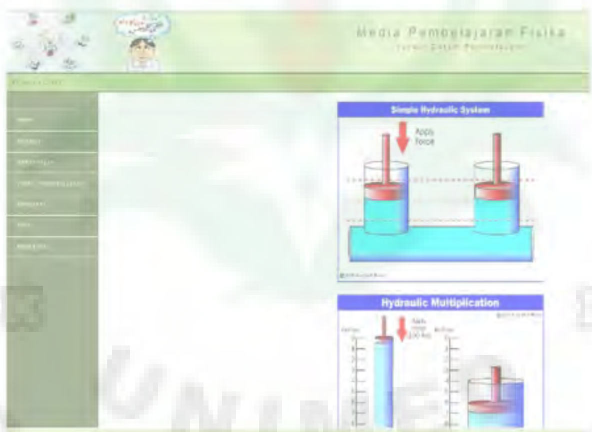


Figure 4:
Appearance of law Pascal application menu on hydraulic pump

Figure 4 displays the learning media with the navigation pane on the left. The background is made plain, to avoid unnecessary mental processing. The topic remains at the top at all time. In Figure 4, when users click the arrow, a window opens and display a simulation as seen in Figure 5. The process is represented by colors and text in an enlarged size.

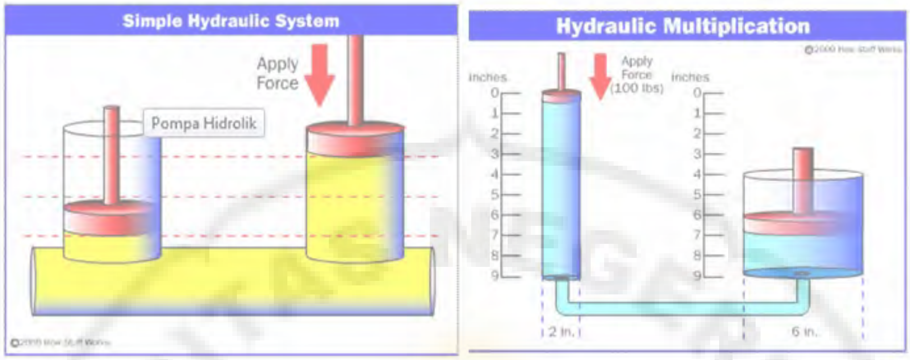


Figure 5:
Pascal legal applications on the hydraulic pump

Figure 6 is a submenu display that shows the phenomenon of Archimedes Principals. In the media the student can observe if the object is inserted into the liquid then the weight of the load will decrease as much as the liquid it displaces, by changing the load inserted into the liquid the amount of water that moves will also vary, thus displaying a different appearance.

Figure 6:
The Archimedes principle

Figure 7 is a submenu display that shows the legal application of Archimedes in everyday life especially on submarines, students can observe and manipulate the conditions of floating submarines and diving.

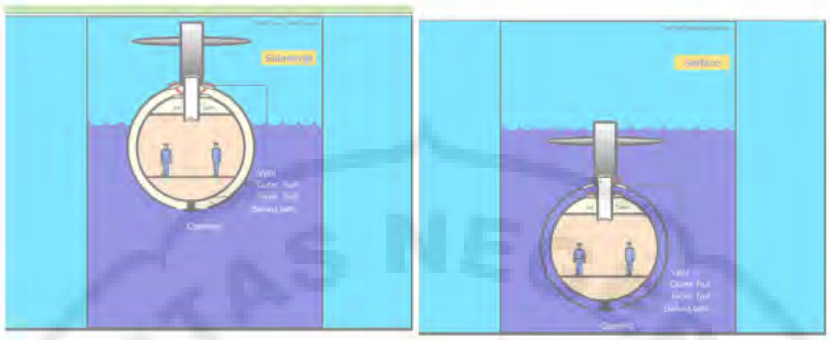


Figure 7:
Applications of legal Archimedes on submarines

Then, the prototype was tested through expert review, in which walkthrough was carried out. It was carried out to determine whether with the designed interface users could easily carry out their tasks or not (Blackmon, Polson, Muneo, & Lewis, 2002). Five experts involved in the walkthrough sessions. All experts have been teaching the field of human-computer interaction and research in the field for at least seven years. In addition to that, they have also consulted projects in the industry. The procedure for the walkthrough session is visualized in Figure 8.

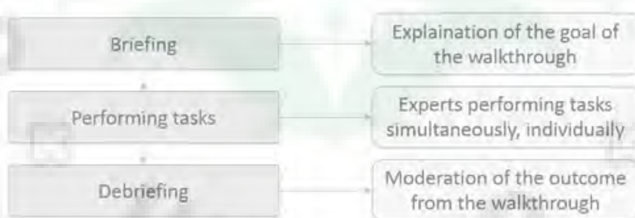


Figure 8:
The walkthrough procedure

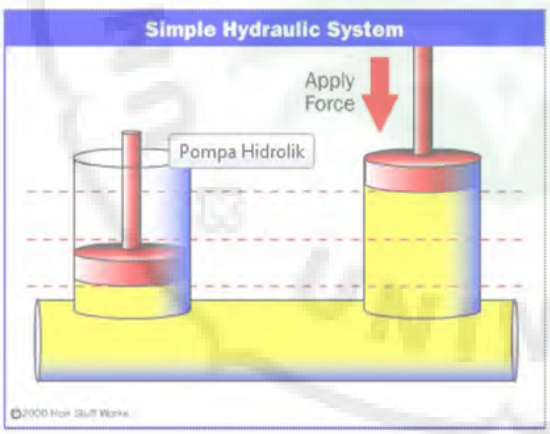
Referring to Figure 8, in the beginning, the experts were gathered together, and the goal of the walkthrough was briefed. They were made understood that the walkthrough was aimed at gathering usability issues, particularly on flaws that increase cognitive loads through unnecessary excise. Then, they were let to walk through the learning media, guided by specific tasks. The tasks are (1) observe the simulation for Pascal law, (2) observe the simulation for submarine, (3) observe the simulation for the regional water company, and (4) observe the simulation for the principle of Archimedes. While walking through the learning media, the experts were noting down all flaws that they found, individually. They were not allowed to discuss during the walking through. Later, in the debriefing session, the experts sit together, discuss what they found. They brainstorm, and moderate the outcomes. Finally, they handed the outcomes to this study.

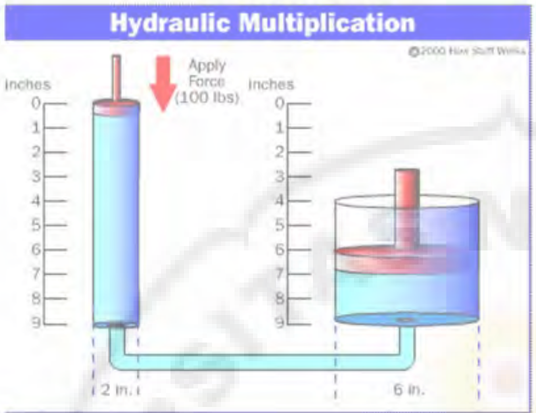
RESULTS

The learning media was developed based on the storyboard that was designed with user intervention. The contents were adopted from the textbook. When experts walk through the learning media, their concern was focused on whether the prototype through the way it interacts with the users, supports user tasks well. In this paper, the user tasks being evaluated is in observing the simulations to understand the content.

Having gone through the walkthrough process, the experts found that the learning media is able to deliver the contents. However, in certain parts, users, users may deal with difficulties, in which some excise appear. Table 1 details the excise that they have found.

Table: 1
Excise in the learning media

Display	Excise and Implication
	**Excise 1. There is no instruction for the users.** **Implication: When there is no instruction, users have to guess for their action (*can cause cognitive load*). They may make mistakes, or wait for some actions from the learning media (*can lead to stress*).** **Excise 2. The arrows have no indication of an active button.** **Implication: When there is no indication, users do not realize that they can be clicked for actions from the learning media, hence, they have to guess and may click on other elements (*can cause cognitive load*).**
	**Excise 3. The objects have no label.** **Implication: When there is no label, users have to guess. Perhaps, users have to find the information from another source (can cause cognitive load).** **Excise 4. The lines have no label.** **Implication: There are three lines, with no label, users have to guess which one means what... (can cause cognitive load).** **Excise 5. Does the color (for the objects) contain certain meaning?.** **Implication: Users may think the color is part of the effects of the simulated action. Hence, they tend to think of the effect (can cause cognitive load).** **Excise 6. The arrow does not indicate the strength of the force.** **Implication: Users have no idea, and they have to make some guess (can cause cognitive load). Or, they understand differently.**



Excise 7. The objects have no label.

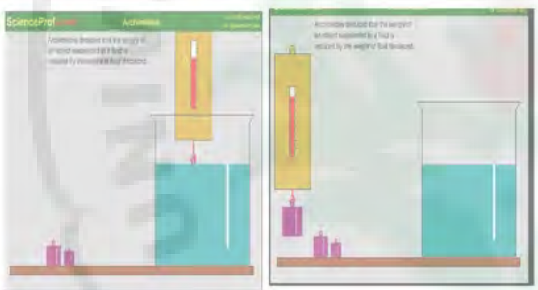
Implication: When there is no label, users have to guess. Perhaps, users have to find the information from another source (can cause cognitive load).

Excise 8. The experiment seems like similar to the simple hydraulic system, but has no line.

Implication: Users may wonder in what way the simulation results in (can cause cognitive load).

Excise 9. Objects use a different color than that in the simple hydraulic system.

Implication: Users may think color means something (can cause cognitive load).



Excise 10. The objects have no label.

Implication: When there is no label, users have to guess. Perhaps, users have to find the information from another source (can cause cognitive load).

Excise 11. There is no indication for user tasks.

Implication: Users have to guess their actions (can cause cognitive load).

Excise 12. The objects have no label.

Implication: When there is no label, users have to guess. Perhaps, users have to find the information from another source (can cause cognitive load).

Excise 13. There is no indication for user tasks.

Implication: Users have to guess their actions (can cause cognitive load).

Excise 14. The label is too small.

Implication: Users have to put extra effort into reading the label (can cause cognitive load).

Overall

Excise 15. The simulations lack caption explaining the experiment.

	Implication: Users have to depend too much on the visual and audio. The text could strengthen the audio and visual. Hence, without text stating important points, learning could be distorted (could cause cognitive load).
	Excise 16. No example in the actual context.
	Implication: Users may not be able to associate the experiment with the actual context. Hence, they have to guess, or it creates fear for them to experience the actual situation (could cause frustration).

DISCUSSIONS and CONCLUSION

Although the learning media has been designed by involving users, and their feedbacks were considered, and signaling principles have been applied, still experts found that users will face difficulties understanding contents from the experiments. Based on their experience while walking through the learning media, they suggest actions in Table 2 be taken.

Table: 2
Recommendations for improvement

	Excise and Recommendation
Excise 1.	There is no instruction for the users. Recommendation: Instructions are placed for every experiment. They have to be step-by-step in the language users familiar most, with a placeholder.
Excise 2.	The arrows have no indication of an active button. Recommendation: when there are elements users are expected to click, make them noticeable. They have to provide cues, either visual cue or audio cue.
Excise 3.	The objects have no label. Recommendation: In all experiments, all objects are labeled. The label should not touch the object, and located on a placeholder. For all objects, the label has to be easily read and standardized (color, shape, font size, etc...)
Excise 4.	The indication of effects and results have no label. Recommendation: All indications of effects and results in all experiments should be labeled/captioned. The labels must be represented differently than the labels for objects. They must be standardized for all experiments.
Excise 5.	Does the color (for the objects) contain certain meaning?. Recommendation: If the use of color is insignificant, use standardized color for all objects.
Excise 6.	The arrow does not indicate the strength of the force. Recommendation: When there is a force, indicate the strength of the force, in the text.
Excise 7.	The experiment seems like similar to the simple hydraulic system, but has no line. Recommendation: For all similar experiments, with similar form of effects, use similar representation
Excise 8.	Objects use a different color than that in the simple hydraulic system. Recommendation: For all similar procedure of experiments, use similar representations.
Excise 9.	There is no indication for user tasks. Recommendation: For all experiments, user tasks have to be clearly indicated, such

	as whether they have to click something, type something, drag somewhere, and etc...
Excise 10.	The label is too small.
	Recommendation: When providing text, ensure the text is readable by the users. This implies color, size, location, contrasts, etc...
Excise 11.	The simulations lack caption explaining the experiment.
	Recommendation: On top of audio and visual explanation, text stating main points is necessary. Provide them to enhance memorability.
Excise 12.	No example in the actual context.
	Recommendation: Provide video showing how the context being experimented takes place in the real situation.

The results of the walkthrough prove that although an interactive learning media is designed with users' involvement, it is not guaranteed flaw free. Designers have to realize that designing learning materials have to be carried out in an interdisciplinary team (Preece, Rogers, & Sharp, 2015). In this study, not only content experts were involved, besides learners, but also experts in human-computer interaction.

Involving experts in human-computer interaction is crucial because they could determine the problems users potentially faced when dealing with the learning media. This could not be performed by other people, including the designer. Based on their experience the human-computer interaction experts have user characteristics in mind already, for the context they are using the learning media. As a result, identifying flaws is easy for them.

Other studies have also involved experts in their development of interactive products like Karajeh, Hamtini, and Hamdi (2016) and Mohd and Shahbodin, (2016). Basically, they also gathered similar results, that expert evaluation discovers a number of a flaw in terms of excise in the interactive products.

All recommendations by the experts are expressed in ensuring users are notified. This is the role of signaling principles. Obviously, signaling principle is important in guiding users while going through the learning media (Austin, 2009). It helps users in many ways. Besides noting users of buttons, menu, it helps to feedback reactions to users, and notifying the status of tasks being carried out. Also, it clarifies format of entry, and availability of something (Amadieu, Mariné, & Laimay, 2011). Obviously, it is more powerful when the interactive application is more complex. Anyway, the learning media in this study is simple; hence the signals it provides to users are limited. It is in line with the goal of the learning media (and any other interactive application), which is to ease user tasks. Hence, unnecessary signaling is totally avoided.

The interactive learning material in this study acknowledges the roles of experts in human-computer interaction. It is strongly emphasized by many gurus in the area of study (like Preece, Rogers, and Sharp (2015) and Mayhew (1999)) to employ experts for evaluating the interface of the designed prototype before deployment. Based on the recommendation by the experts, this study will take appropriate actions in improving the interface.

Further, this study intends to carry out a user test after the prototype is improved. Besides expert evaluation, this study believes that user test is also important before the learning media is deployed, as has been carried out by various works previously (Aziz, Roseli, & Mutalib, 2011; Mayer & DaPra, 2012). In fact, it is also strongly emphasized by the experts like Nielsen (1994), Preece, Rogers, and Sharp (2015), Schneiderman, Plaisant, Cohen, Jacobs, Elmqvist, and Diakopoulos (2016).

Regarding signaling principles, designers have to understand that too much signaling is also annoying users (Mayer, Heiser, & Lonn, 2001; Mayer & Fiorella, 2014). It is analogous to a person that tells too much, even in situations where people do not expect any information. When the person keeps telling, and others have to respond to it, it is unnecessary. Hence, providing signals to users should be carefully considered, to ensure important signals are not left unattended, and that no unnecessary signal is loaded.

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