# Visualizing (past) decision making for self-regulation

**Lianne de Jong**
Department of Industrial Design, Eindhoven University of Technology
Eindhoven, the Netherlands
l.c.d.jong.1@student.tue.nl

## ABSTRACT

This research is situated in the lower-classes of secondary schools in the Netherlands. It presents a new application of FireFlies2, which are earlier designed interactive tangible pixels which can be distributed over the classroom. The objects are used by the students to set a specific colour based on his/her decision. Within the scope of this research two existing decision moments are define. One during the explanation phase 'join the explanation or work independently' and one during the work 'individual or open for collaboration'. These two decisions are treated as case-studies to analyse how a peripheral visualization of (past) decision making can stimulate the self-regulating behaviour of students. The results show mainly positive experiences from both students and teachers on an interaction level. On an intervention level the results show an effect on the reflective ability of students, but further research is needed to correctly interpret this effect.

### Author Keywords

Self-regulation; ambient information display; data visualization; secondary school.

## INTRODUCTION

This research is situated in the lower classes of secondary schools in the Netherlands. Within this context the focus lies on the beta-lessons, such as mathematics; chemistry and physics. This paper presents an exploratory study on a new application of FireFlies2. These interactive tangible pixels which can be distributed over the classroom are designed (and researched) earlier by e.g. D. Verweij and S.Bakker [17]. Unique for this research, in relation to earlier research with fireflies, is that the primary focus lies on students (rather than teachers). How can we use Fireflies to improve the experience of students in the lower-classes of secondary school? With this question in mind three different co-constructing stories sessions were hosted with a total of nine teachers. One thing that all teachers agreed upon was a drive to teach students to become self-reliant. This drive is in line with the mission statement of the school, Theresia Lyceum, where this research is situated. Literature shows proof that this need for self-reliant students is more widely acknowledged within the context of Dutch Education [8, 11]. This combination led to the general challenge of this research: how can we use fireflies to stimulate students to become more self-reliant.

In order to become self-reliant, students need to become more autonomous. This can be done i.e. by giving students the possibility to make their own decisions [15]. If students can decide 'how' they learn themselves, they are likely to feel more ownership of their own learning. In order to enable students to make such decisions, they need to become aware of their own behaviour. This awareness can by stimulated by increasing self-regulating behaviour such as reflection and self-evaluation [14]. Together this led to the following research question: "How can a peripheral visualization of (past) decision making stimulate self-regulating behaviour of students in the lower-classes of secondary schools?" In this research a new application of the FireFly will be used as a design intervention to (indirectly) change this behaviour. On top of this an analysis on interaction level, the way the design is used and understood, is essential for a meaningful evaluation [5]. Therefore, the effect of a design that visualized (past) decision making is evaluated on both interaction and intervention level.

Within the scope of this research the focus is on two existing 'decision moments' in class context, one during the explanation phase and one during the work phase. Within the explanation phase students can choose to either join the explanation or to work independently in silence. Within the work phase students can choose to work individually or to be open for collaboration. These two decision moments will be treated as case-studies to answer the earlier defined research question. The fireflies 2.0 will be re-designed and used as an intervention to stimulate reflection and self-evaluation within these two decision moments. In order to analyse the self-regulating behaviour of students a within-subject analyses based on a validated questionnaire will be conducted over a timespan of three weeks. On top of this qualitative data will be gathered via open questions, semi-structured observations and teacher interviews. This paper will present the set-up and findings from this user study and discuss insights based on these findings. Next to discussing the limitations of the work and the possibilities for the future. All together this will lead to a conclusion in relation to the stated research question.

## THEORETICAL BACKGROUND

The stated research question examines the relation between two different concepts, namely: 'peripheral visualizations' and 'self-regulating behaviour'. In order to understand the

relation between two different concepts it is important to reach agreement on the definition of these concepts.

### Peripheral visualizations
It is abundant to say that within class context the focus of attention should be on learning (for students) and teaching (for teachers). When looking at interactive systems the majority of interactions take place in the centre of attention, the so called 'focused interaction'. The field of learning analytics that aims to support learners and teachers through dashboard applications emerges rapidly. However, these systems can often only be interpreted in the focus of attention. This type of information display can be very useful to convey large amounts of data but is not suitable for in context real-life interaction in class context. According to Bakker et. al. it is possible to interact with digital information at the periphery of attention, enabling so called 'peripheral interactions' [4]. By creating a design that can communicate data in the periphery of attention student and teachers can use the focus of their attention on learning and teaching. This so called, ambient displays, which can be perceived in the periphery of attention typically communicate just one, or perhaps a few at the most, pieces of information. [12].

### Self-regulating Behaviour
According to the PISA studies from OECD in 2012 too many Dutch students lack the level of persistence, drive, motivation and believe in their own skills to flourish [9]. Especially for mathematics nowhere in the western world student score lower on intrinsic motivation than in the Netherlands. According to the self-determination theory autonomy is one of the key elements for intrinsic motivation. This need for autonomy and self-reliance are intertwined and positively connected in both ways. Next to this potential positive effect on (intrinsic) motivation, the stimulation of autonomy (and ownership) are leading principles in teaching future-ready students [8].

Overall, it can be concluded that there is a major need for self-reliant students, who can act autonomous and feel ownership of their own learning. This brings us to a new curricular challenge, because it is not yet known how to teach self-reliance (or self-direction) the way we know how to teach long division [13]. A possible first step in teaching self-reliance is the stimulation of self-regulating behaviour. Since this ability is essential in becoming an individual who is able to self-direct learning processes.

Within this research the Self-Regulation of Learning Self-Report Scale (SRL-SRS) is used as an instrument to examine the self- regulation of learning as an individual attribute of each student. The complete SRL-SRS comprises six subscales: planning, self-monitoring, evaluation, reflection, effort and self-efficacy [14]. Based on feasibility and the chosen intervention the focus of this research is on the scales for reflection and self-monitoring.

### RELATED WORK
As described earlier more research has done on the possible effect of FireFlies in classroom context. While the focus of this research is different, earlier gained insights shaped the bases of the current research scope and focus.

### Primary School
Initially the FireFly is designed as an open-ended design tool to support primary school teachers in performing several secondary tasks [3]. In this version of the design only the teacher could actively interact with the FireFlies. The objects were used to display information about and to the pupils. In later research the functionalities were re-designed in such a way that the tool enabled for a two-way communication between pupils and teacher. With FireFlies2 students could control the upper-part of the light object (to send information) and teachers could control the lower-part of the objects. The goal of this re-designed FireFly2 is to decrease the cognitive load of teachers by converting some internal task to the interactive tangible pixels [17]. Both works show that the designed tool allows for peripheral interactions in classroom context, without too much distraction from primary teaching tasks. However, the focus of both works is on the secondary tasks of primary school teachers.

### Secondary School
In secondary school context the FireFlies have been used as 'ClassBeacons' to visualize the physical proximity of the teacher. This functionality can stimulate teachers in providing more differentiated instructions by offering interpersonal interactions. Furthermore, the information can possibly be used by the students to increase involvement and encourage active participation [2]. Next to this Bernice d'Anjou is currently using FireFlies in the context of online working in secondary school classes. By visualizing the 'time spent' in relation to the amount of 'completed exercises' teachers can gain more insight on the effort and performance of their students. While this data was already available in existing learning dashboards, the ambient distributed visualization allows the teacher to walk around (and interact with students) while simultaneously checking the visualized information. In this approach there is no active interaction with the FireFly from a student perspective. So far, all earlier research is focused primarily on the teacher. Therefor insights about the possible effect of this design intervention on (the behaviour of) the student is rather limited.

A different tool designed to visualize data from learning analytics to secondary school teachers is 'Lernanto'. The goal of this ambient information display is to provide teachers with immediate data access to support them to

distribute their attention in a more effective way [1]. This work shows how the immediate visualization of information can improve the interaction between teachers and students. However, it was also noted that the mapping between the separate 2D display (in the back of the classroom) to the location of the actual students could cause struggles for the teacher. Therefore, the design of the distributed FireFly object is preferred over 2D displays such as Lernanto.

## DESIGN

Within this research a new application was given to an existing prototype called 'FireFlies2'. "The light-objects are semi- transparent 3D printed shells placed on a sturdy base and contain four Light-Emitting Diodes (LEDs)" [17]. The colours of the top parts of these light-objects can be set locally by the students by rotating the artefact (figure 1). The lower part of the light object can be controlled via a dashboard interface or a tablet application. However, these functionalities were not used during this research.



**Figure 1. Colour indications FireFly2.**

### Co-constructing Story Sessions

At the start of the research process three different co-constructing story sessions were organised in order to get a better understanding of the context. "Co-constructing stories is a participatory design technique for early, formative concept evaluations to elicit in-depth user feedback and suggestions" [6] Each session was split into two phases and lasted 45-60 minutes.

During the first phase 'sensitization', two different existing scenarios were presented and discussed. One scenario of a 'normal' lesson using books and one using laptops (since laptops had already been introduced in the lower-classes of this specific school). The goal of this phase is to check the assumptions made about this context, gain more insights about the existing situation and trigger anecdotes to refer back to in phase two. During the second phase 'elaboration', a new scenario was presented introducing the personal light-emitting objects. The goal of this phase was to gain insights on possible new applications of the design and find meaningful data to visualize about the students and their performance. The combination of these two different

phases is summarized in figure 2. In order to stimulate an interactive discussion during the elaboration phase two different sketch templates were provided. One template of the FireFly object and one template of a classroom scenario (during work time) with FireFly objects on each table. In practice the templates were annotated/ made by the designer(s), since teachers found it hard to express themselves in a non-verbal way. All provided materials, both scenarios and sketch templates, can be found in appendix 1.

Three different sessions were hosted with a total of nine different teachers (4 male; 5 female) each from the same school. For practicality reasons it was decided to host one session with multiple teachers. The first two sessions took place with two teachers and the last session had five teachers. The teachers were selected in such a way that there was a variation in taught subject and amount of experience. Furthermore, the sessions were audio-recorded only, because the impact of the presence of camera in relation to the added value of video recordings, was experienced as undesirable.
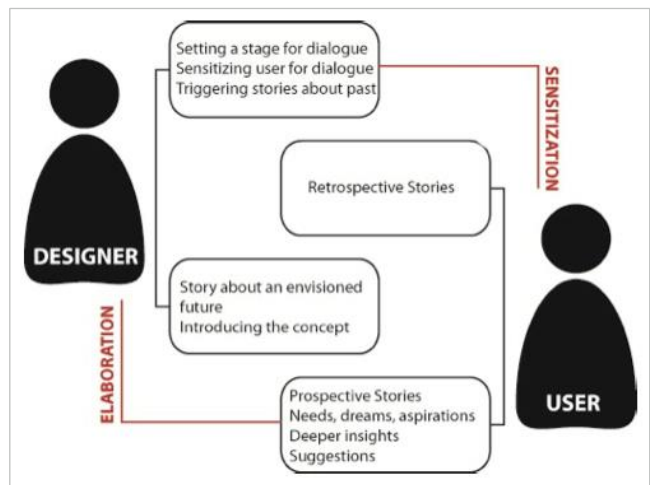


**Figure 2. Phases of co-constructing stories [6].**

### Implications for Design

When discussing the sensitizing scenarios all teachers confirmed that they recognized only two different phases (rather than three). One explanation phase, where the teacher explains (new) content and/ or answers questions. And one work phase, where the students make exercises and/ or start on their homework. When discussing the possibilities for data visualizations different challenges and opportunities occurred. A straightforward application that came up during all sessions concerned the topic of asking questions. While some teachers were enthusiastic about this idea, others were afraid they would not see a colour changing object as easily as they see a raised hand. Besides this rather practical application is less interesting from a research perspective.

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Furthermore, all teachers had experience with laptop/ computer settings and therefore (some form of) learning analytics. While most of them recognized the added value of this data there were serious concerns about the privacy of the students when displaying that type of information. Especially the more experienced teachers indicated that they are able to judge the performance level of their students during class. They often know who the 'weak' students are within their subject, which students can use extra challenges and what topics are experienced as difficult. Furthermore, all teachers value an open and safe atmosphere of their students. Some believe the 'public' confrontation of performance level could damage this atmosphere. Overall it was concluded that the added value of extra information about student performance does not out way the effects on the privacy and safety of the students.

On the other hand, data about the activity level of the students was experienced as less confronting than data about the performance level. When working online data about progress in relation to time could be gathered and visualized, which most teachers recognized as valuable information. However, currently only a part of the work is done online. Besides these types of applications are very similar to the earlier discussed work of Bernice d'Anjou. Another activity that was recognized by all teachers was the possibility to already start working independently during the explanation, rather than listening. Some teachers did see an added value of visualizing that information, so they know which students they can involve/ ask questions.

### Scenario of Use
Based on the related work and the input from the three different sessions it was decided to focus on the student rather than on the teacher. Each student was given one FireFly and instructed to indicate their chosen approach by setting a certain colour. On the one hand students could decide to either listen to the explanation (by choosing yellow) or to work independently (by choosing red). On the other hand, they could decide between working alone (by choosing red) or together (by choosing blue). These two decision moments correspond with the two possible phases indicated by the teachers; the explanation – and the work phase. Resulting in two possible landscapes of distributed tangible pixels indicating the chosen approach of each student for that specific phase (figure 3).

The used prototype could be set to four different colours: green, yellow, red and blue. Within the scope of this research there was no application for the green colour. The other colours were used to indicate a decision made by the student (figure 4).
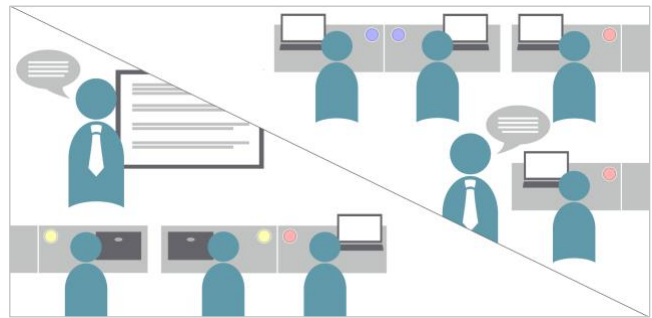


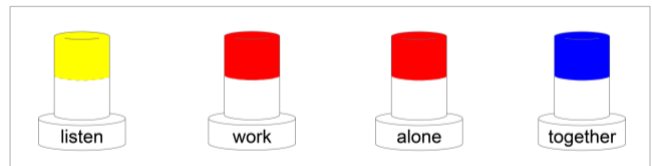**Figure 3. Scenarios explanation phase and work phase.**



**Figure 4. Colour distribution explanation- and work phase.**

### USER STUDY SETUP
The user study lasted three weeks and took place in three different classes. One first-class of 30 students during mathematics and two third-class students, one of 28 students during chemistry and one of 29 students during biology. Each class had two hours per week of that specific course, one on Monday and one on Friday. During this period each student received a FireFly to indicate his/her choice if possible. During the test period all students were observed and before and after the test period each student was asked to complete a survey. Finally, a one-on-one interview took place with two teachers to discuss his/her experiences and future possibilities.

### Entry Survey
In order to evaluate the self-regulating ability of students in a quantitative way a within subject analysis was conducted. The survey questions regarding this topic are based on a validated questionnaire: Self-Regulation of Learning Self-Report Scale (SRL-SRS) [14] Within the SRL-SRS six different subscales are defined: planning, self-monitoring, evaluation, reflection, effort, and self-efficacy. As described earlier it was decided to focus on reflection and self-monitoring. Originally the subscales of reflection consisted of five items and self-monitoring of eight items. However, a part of the self-monitoring questions focused specifically on the quality of the work. Since the intervention did relate to the way of working rather than the work itself these questions were removed. Furthermore, all questions were reformulated in such a way that the answer could be given on a five-point Likert scale ranging from (1) strongly disagree to (5) strongly agree. Finally, all questions were translated to Dutch, since the survey was conducted on a Dutch secondary school.

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Next to these nine closed questions, the survey consisted of three open questions. One concerning the current decision moment during the explanation phase, one concerning the current decision moment during the work phase and one question about reflecting on the relation between behaviour and learning. The goal of these questions is to get a better understanding of the target group and their current behaviour. This information was used as the base of both the observations and the teacher interviews. The full survey as distributed to all students can be found in appendix 2.

**Semi-structured Observations**
Before implementing the intervention two classes were observed for one hour and all classrooms were visited. This was done to minimize assumptions and to be able to better interpret the student behaviour during the intervention period. In a more practical sense this observation moment was used to create observation templates of all classrooms. During the intervention each student received one FireFly which was placed on the corner of the table (Figure 5, 6). During each class all colour changes were noted per location on a set template. Since all involved teachers worked with fixed floorplan, this method allowed for student specific data without hurting the anonymity of the students. A summary of the gathered data can be found in appendix 3. Next to this structured observation, annotations were made for irregular activities and noteworthy events. These notes were used as input for the teacher interviews and to better interpret the observed colour changes.



**Figure 5: User test setup Chemistry classroom**



**Figure 6: User test setup regular classroom**

**Evaluation Survey**
In order to conduct a within-subject-analysis the closed questions of the survey were asked both before and after the intervention period. Next to these closed questions, four

open questions were formulated. These open questions were used to gather qualitative data about the reflective ability of the students. The first question referred to the action (set the FireFly colour) in itself and evaluated whether this action triggered more conscious decision making (in the perception of the students). The other three questions were used to evaluate the aspect of 'past' decision making. Due to both technical and practical reasons it was not possible to implement this into the current intervention prototype. However, via the survey students were 'confronted' with their most recent past decision and asked to (re)-evaluate this decision. Based on this evaluation students were asked to think about possible future decisions in similar situations. Finally, students were confronted with 'trends' in their overall behaviour during the past three weeks and asked to interpret this information and (if possible) use this for the future. Through these questions the aspect of 'past' behaviour in relation to reflection, and therefore self-regulation, can be evaluated.

Due to many irregularities in the third classes it was not possible to recognize 'trends' in their behaviour. Therefore, the last survey question was replaced with a question about their overall experience with the object and how they believed this influenced their behaviour. Both versions of the survey containing the specific questions, as formulated (in Dutch), can be found in appendix 4. It is important to note that, within the scope of this research, there is no distinction between right or wrong decisions. The purpose of these questions is to trigger reflection and to evaluate whether students are able to self-regulate their behaviour.

**Teacher Interviews**
While the focus of this research is on (the behaviour of) the students a 30-minute interview was conducted with two of the involved teachers after the intervention period. Teacher 1, who taught the first-class and teacher 2, who thought chemistry to one of the third classes. This was done because it is very hard to interpret the behaviour of ±30 unknown individuals, especially without a point of reference. Since the teachers are more familiar with the students and their 'normal' behaviour they could give more meaning to the observed situations. Furthermore, the constant interaction between students and teachers is fundamental to the behaviour of both parties in classroom context. Every change the teacher makes affects the students and each change in student behaviour affects the teacher. Making it almost impossible to research one of them without involving the other party as well.

Next to discussing the student's behaviour and teacher's experiences during the intervention period, the interview was used to discuss possible future scenarios. As described earlier the functionalities of the lower-part of the FireFly were not used. However, several future applications can be extracted from the gained insights in relation to the current research question. For instance, the lower-part could

'confront' students with past experiences, in order to trigger reflections. Another possibility is to use the lower-part as a feedback mechanism for the (contrast) between intended and actual behaviour. Finally, the possibilities of online working and learning analytics could be used to give an advice on behaviour that suits the performance of that specific student. A visual overview of all discussed future possibilities can be found in Appendix 5. The input from this part of the interviews is processed in the 'Future Possibilities' part of the discussion of this paper.

## FINDINGS

Quantitative and qualitative data was gathered by distributing a survey with both open and closed questions. Furthermore, observations were made and discussed to gain more insights about the 'why' behind certain behaviours.

### Quantitative Student Data

The first five questions of the survey related to the subscale reflection. In order to calculate a 'reflection score' the mean of all given answers was calculated per student. The survey was completed by ±87 students, $N_{start}$=80; $N_{end}$=84 (table 1). A visual overview of the collected data can be found in the histograms in Figure 7 (start survey) and Figure 8 (evaluation survey).

|       | N  | Mean   | Std. Deviation | Std. Error Mean |
|-------|----|--------|----------------|-----------------|
| **Start** | 80 | 3.5819 | .52496 | .05869 |
| **End**   | 84 | 3.3970 | .59356 | .06476 |

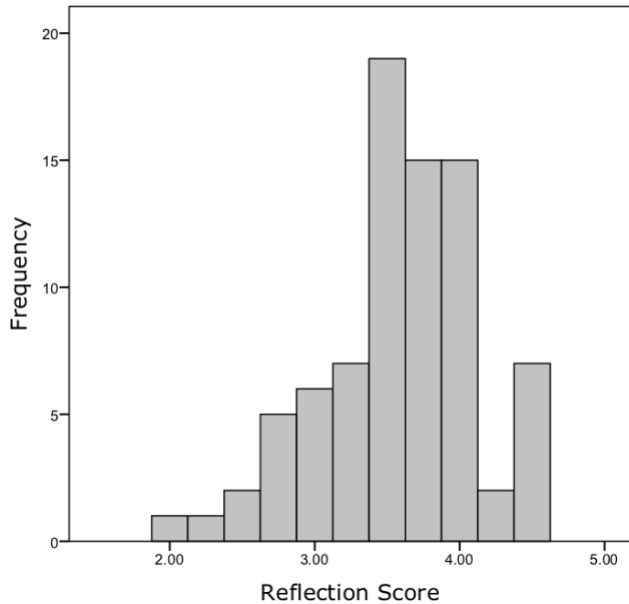**Table 1: Descriptive Statistics Reflection Score**



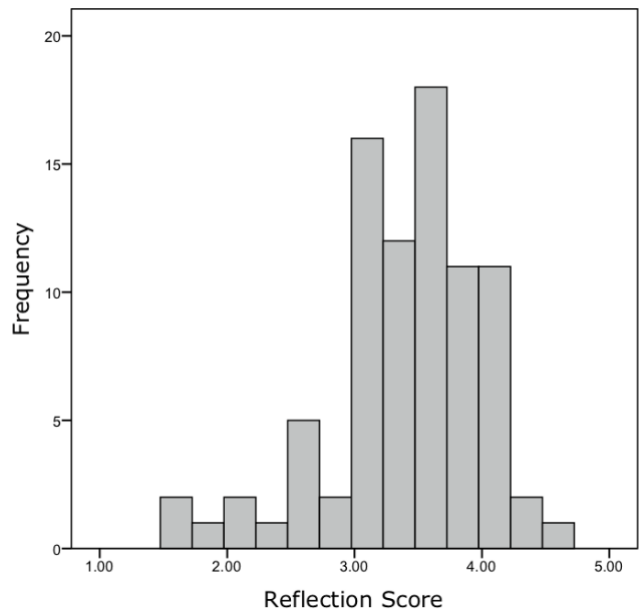**Figure 7: Reflection Score before the Intervention**



**Figure 8: Reflection Score after the Intervention**

To compare both groups an independent sample test has been conducted. According to Levene's test for equality of variances p=.716, so equal variances can be assumed (p>α, α=0.05). In conclusion there is a significant difference in reflection score before the intervention (μ=3.58, σ=.525) and after the intervention ((μ=3.40, σ=.594); t(162)=2.11, p=0.037. These results suggest that the intervention does have an effect on the self-reported reflection level of the students. Specifically, the findings suggest that the reflection decreases after a three-week intervention period.

|                           | t     | df      | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
|---------------------------|-------|---------|-----------------|-----------------|------------------------|
| Equal variances assumed   | 2.109 | 162     | **.037**        | .18485          | .08766 |
| Equal variances not assumed | 2.115 | 161.131 | .036          | .18485          | .08740 |

**Table 2: T-Test Reflection Score**

Question six to nine of the survey related to the subscale self-monitoring. A 'self-monitoring score' per student was calculated using the same approach. Since these questions were part of the same survey the sample size is identical (table 3). A visual overview of the collected data can be found in the histograms in Figure 9 (start survey) and Figure 10 (evaluation survey).

|       | N  | Mean   | Std. Deviation | Std. Error Mean |
|-------|----|--------|----------------|-----------------|
| **Start** | 80 | 2.9672 | .73070 | .08169 |
| **End**   | 84 | 2.9926 | .82878 | .09043 |

**Table 3: Descriptive Statistics Self-Monitoring Score**
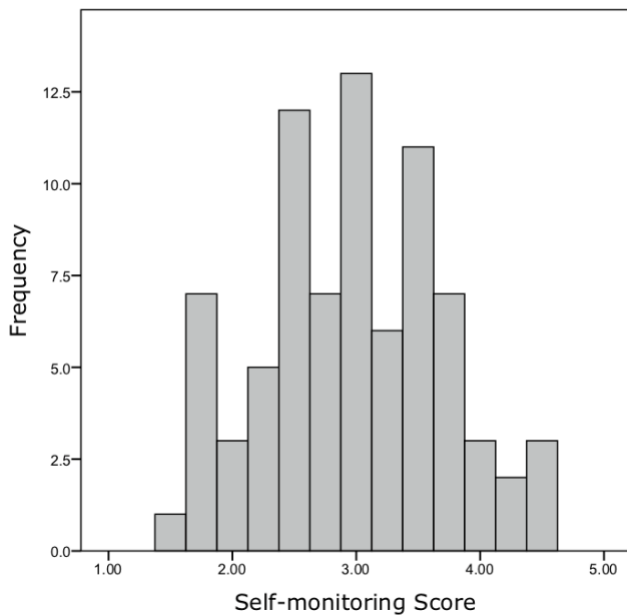
**Figure 9: Self-Monitoring Score before the Intervention**
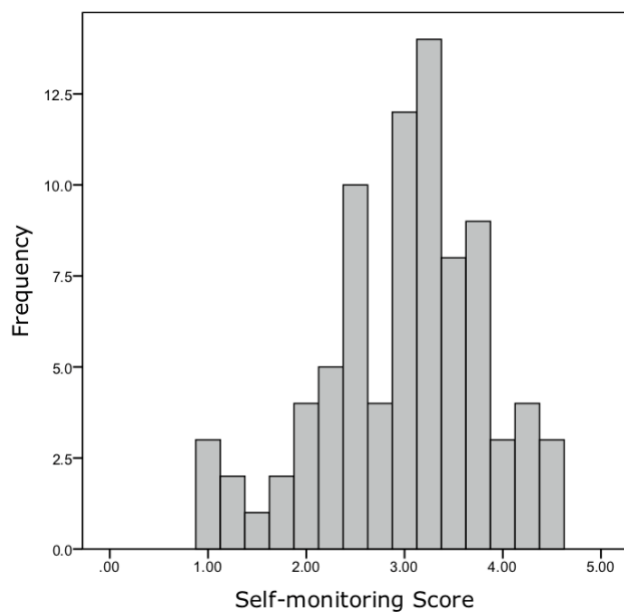


**Figure 10: Self-Monitoring after the Intervention**

To compare both groups based on a different criterium, the same analyses have been conducted. According to Levene's test for equality of variances p=.449, so equal variances can be assumed (p>α, α=0.05). According to the independent T-Test it can be concluded that there is no significant difference in self-monitoring score before the intervention (μ=2.97, σ=.731) and after the intervention ((μ=2.99, σ=.829); t(162)=-0.208, p=0.836. These results suggest that the intervention did not have an effect on the student's self-reported level of self-monitoring.

| | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
|---|---|---|---|---|---|
| Equal variances assumed | -.208 | 162 | **.836** | -.02537 | .12224 |
| Equal variances not assumed | -.208 | 161.056 | .835 | -.02537 | .12187 |

**Table 4: T-Test Self-Monitoring Score**

**Qualitative Student Data**

Via an open question student were asked if they made more conscious decisions. The majority of students indicated that they did not feel like they made more conscious decisions. Students with this opinion had several type of explanations: they did not see how a light object could do that; that they already had a preferred way of working; that they already made conscious decisions before the intervention; that they only saw a use of the light indication for the teacher. However not all student did give a clear explanation of their opinion. The students that did indicate that they made more conscious decisions had the following opinions: the object was recognized as a trigger for thinking; they were more aware that they actually had a choice, they made more use of the 'work independently' choice during the explanation phase, they saw the light as a signal to their neighbour; they considered more conscious if they needed explanation.

To get grip on the majority of the different groups the answers have been divided in a few clusters. Table 5 shows the amount of answers within each cluster between brackets ($n_{answer}$), each answer representing one student. Next to the defined clusters there were three students that indicated that they felt bothered by the intervention and one student that answered that he/she did not know the effect of the object.

| | |
|---|---|
| Yes (29) | With explanation (23) |
| | Without explanation (6) |
| A little (7) | |
| No (47) | Not really (7) |
| | With explanation (18) |
| | Without explanation (19) |

**Table 5: Conscious Decisions Clusters**

When 'confronted' with their indicated decision from the lesson before and asked to (re-)evaluate this decision students gave the following type of answers:
- Overwhelmed/ frustrated (2)
- Unable to remember (11)
- Neutral about experience (6)
- Experience 'as usual' (8)
- Positive about experience (42)
  - With explanation (15)
  - Without explanation (27)

When asked whether they would make the same decision in a similar situation (and to explain why), students were:
- Reluctant/ unable to answer (13)
- Unable to say/ did not know (9)
- Would do the same (35)

- o With explanation (17)
- o Without explanation (18)
- Would do something different (5)
  - o With explanation (5)
- Dependent on the situation (7)

When confronted with 'trends' in their overall behaviour and asked whether this information could be used for future decision making the following answer-clusters emerged:
- Recognizes behaviour and is able to translate the received information to the future (14)
- Recognizes behaviour but sees no purpose (6)
- Shows doubt/ sometimes (2)
- Cannot remember his/ her behaviour (5)
- Emphasizes that both behaviour and decisions are situation dependent, unable to use information (2)

Note that the frequencies (per cluster) are lower because this specific question was only asked to the first-class.

Both third-classes were asked about their overall experiences and how this influenced their behaviour. From these answers the following clusters emerged:
- The object is perceived as something to play with and/ or a distraction (6)
- No purpose or effect is recognized (11)
- Overall good/fun experience, but sometimes distracting/ too playful (5)
- Overall good experience on an interaction level, but no connection is made to behaviour (7)
- The object is mainly useful to the teacher (10)
- The object is useful to teachers and students (3)
- Positive experience, due to more clarity/ higher concentration and/or a calmer atmosphere (15)

**Qualitative Teacher Data**
Initially both teachers experienced the intervention as a positive change. Teacher 2 indicated that the period of three weeks was maybe too short to really see an effect. However, teacher 1 noted the students picked it up really quickly. In both classes there was some playing with the objects, but the teachers did not experience this as very disturbing. It was noted that the majority of the students recognized the object as a mean for communication rather than a piece of toy quite quick. When asked about the student that did play with the object for a longer time these students were recognizes as either 'playful' (meaning that they were playing with other objects as well before the intervention) or 'technically-oriented' (meaning that they were probably interested in how the technology worked/ looked from the inside). However, there were some students that did play with the objects a lot, while they were normally perceived as serious students.

Both teachers indicated that they did not necessarily give more freedom of choice during the intervention period. However, the physical presence of the FireFlies did remind time to name the decision moments more explicitly to the students. As a teacher the yellow-red indication during the explanation was experienced as a nice feature. Teacher 1 noted that he was under the impression that he already knew which students wanted to join the explanation but was confronted with another reality due the light-objects. The blue-red distinction during work time was experienced as less useful by the teachers. However, they could imagine that the information could be useful to fellow students. Teacher 1 explained that he would be willing to temporarily move students to different spots in order to allow 'blue' students to work together. On the contrary teacher 2 noted that this could be mis-used by students and that the fixed floorplan was made for a reason.

**DISCUSSION**
Looking at the data gathered from both students and teachers resulted in several insights on interaction and intervention level. However, the work did have several limitations due to irregularities and everyday situations. Overall the work led to some interesting future possibilities for (re)design of the object themselves for the given context and for new research possibilities.

**Insights on Interaction Level**
Overall the majority of both students and teachers experienced the intervention as positive. However, the effectiveness of the intervention in its current form is very dependent on class dynamics. More structured lessons and a consistent teacher's approach create more possibilities for 'proper' use of the tool. If used in a proper and consistent way the intervention led to more clarity for both students and teachers. There were several signs of a calmer atmosphere and some students indicated that they were able to concentrate better. On the other hand, irregular use led to a longer novelty effect and therefore more restlessness. Students often found the tool fun to play with, which resulted in many distractions for either the student him/ her-selves or the ones around them.

Despite the fact that the focus of this research was on the behaviour of the students, the tool in itself is initially designed for teachers. The peripheral overview, which is one of the main assets of the initial design, is not explicitly experienced by any of the students. However, the red/yellow indication was experienced as pleasant and insightful by the teachers. It is interesting to note that quite some students noticed this attribute as well (although they were not asked/ instructed about it). While the visual overview was mainly valued by teachers, the added degree of freedom and enhanced decision moment was recognized and valued by students as well.

The blue/red indication could be more interesting to students. However, this distinction was not actively recognized or used by the students (yet). While many of them triggered each other to switch to blue (when they wanted to work together), there were almost no signs that a

red light was seen as a threshold to approach/ disturb their fellow students.

**Insights on Intervention Level**
Due to the intervention both teachers and students indicated that they were more aware of the fact that there is a choice moment. This little increase in freedom of choice and therefore autonomy could have a smal effect on the self-directedness of the students. However, this effect is not measured or questioned within the scope of this research. While they were more conscious that there was a choice, the majority of students did not necessarily decide in a more conscious way. Partly because many of them had a clear preference for either one and partly due to reluctance/ inability to think about that type of behaviour.

From the quantitative analyses it became clear that there was no significant effect on the self-monitoring ability of the students. A reason for this could be in the formulation of the asked questions, since these were all task/ work specific. In the interpretation of the students this type of words is probably related to the (home)work and the exercises they make. However, the discussed decision moments took place on the level of approach and way of working. Since it might be hard for students to make this distinction in their head, there is a risk that the questions were partly mis-interpret, which would have influenced the results.

On the contrary the reflection score did show a significant difference. When comparing both groups, the overall mean became significantly lower after the intervention. This means that the students are less reflective, which is not in line with what was intended. A reason for this could be that all values are determined by self-report questions. A lower score might indicate that the students became more critical about their own behaviour. Which is actually a positive effect, since critical thinking is essential is for reflecting [10]. Next to these numeric self-reported results on reflective ability, qualitative data was gathered via multiple open questions. From the given answers it can be concluded that many students are unable to show written evidence of their reflective ability. The majority is able to recall his/ her behaviour (given a short time interval). But the reasons 'why' and the deeper/ more abstract explanations are very minimal. The struggle seems to be even bigger when asked to translate this towards implications for the future. It must be noted that the asked questions were regarding the decision options (listen/work and alone/together), which might seem as very straightforward behaviour. Within the scope of this research no qualitative data is gathered about the overall reflective ability of students, no questions were asked regarding different types of behaviour.

**Limitations of the work**
In the everyday life of secondary school teachers, no class, lesson or hour is the same. Therefore, a three-week research period in this context is defined by irregularities and ad-hoc situations. Teacher 1 taught mathematics to a fist-class and had a relatively consistent schedule. Each lesson was set up in a similar way, introduction - homework questions - explanation new theory – work time. In this context the tool (almost) immediately was used as intended and there was little to none playing. Therefore, the results from these students can be perceived as more reliable. As a point of reference, the quantitative data (split by class) can be found in appendix 6.

Teacher 2 taught chemistry to one of the third-classes, which led to classes with experiments, demonstrations and 'element-bingo'. During these classes there were no decision moments for the student, at least not the ones defined beforehand. In consultation with the teacher the FireFlies where still distributed but students did not really know what to do with it. On top of this third-classes are known to be a bit more restless than first-classes. This combination led to more playing and less intended use of the tool. Both teachers and students were able to share experiences and insights, but the novelty effect is definitely bigger in this group.

Teacher 3 taught biology to the other third-class and had one guest lecture and one test during the research period. On top of this personal circumstances of the teacher led to many cancelled classes and in the end cancelation of the interview. Next to these teacher-related irregularities there appeared to be quite some friction between different students it that class. These frictions did not lead to any outburst during the intervention period, nor was there a direct influence on the gathered data. However, this situation might have implicitly influenced the behaviour and opinions of the students (and the teacher). As described these irregularities led to a slightly different version of the evaluation survey. While this was not intended the answers created interesting insights on interaction level and triggered new design implications.

**Future Possibilities**
During three weeks of using the design in a room with ±30 adolescents quite some technical failures occurred. While both students and teachers indicated that they would like to use such the tool for a longer period of time the sturdiness should be improved before this can be realized. Especially when the students worked with laptops the tables were so full that the objects were accidently pushed off while working. A more fixed object (attached to the tables) would be more suitable for these situations. This fixed object could also improve the visibility of the objects for the teacher, since the current form tends to disappear between all the laptop screens. During book-based lessons the visual colour indication was perceived more positively. Except for the yellow colour which was often very hard to see, mainly because many classrooms are designed with a lot of daylight. A re-designed object should either have a different colour or much brighter light.

Next to these practical design implications that became apparent while using the FireFlies for a longer period of time in secondary school context, several new functionalities were considered. In its current form the lower-part of the FireFly remained unused. In relation to the current research question this part could be used as a visual reminder of 'past behaviour'. This visualization could than function as an extra trigger for reflection, when making new decisions. Both teachers believed that such a functionality could work as long as the past situation was similar enough to the present situation (which is not necessarily the previous lesson of that course). This 'past behaviour' could also be visualized as an average value of that period. Teacher 1 believed this would be more interesting and would be interested in this information himself as well. Teacher 2 indicated that this nuanced information might be too hard to interpret by the students. The student's survey answers give reason to believe his concern.

Another option would be to use the object as a means for feedback between intended and actual behaviour. Both teachers noticed technical difficulties in realizing such a functionality. Teacher 2 had strong ideas about replacing this type of 'feedback' by technology. A colour indication lacked the nuance and interaction one can give as a teacher. The final discussed option was an advisory functionality based on either performance or desired behaviour. Both teachers indicated that such an advice could be interesting but the extra workload of giving this type of advices is highly undesirable. An alternative would be an automatically generated advice based on learning analytics. However more research is needed in order to generate good and personalized advice. Besides it can be questioned whether this functionality will have negative effects on the autonomy and self-regulating behaviour of students.

## CONCLUSIONS
Looking back at the experiences of both students and teachers it can be concluded that the aspect of peripheral visualization is valued mainly by teachers. The design of the FireFly allows for an ambient display that allowed teachers to register the decision made by students in one glance. This attribute of the design is especially valued by teachers during the explanation phase. In a similar way the (red/blue) distinction could function as an ambient display for students during the work phase. However, within the given timespan, there were no evident signs of student recognizing this colour-signal from fellow students.

Overall the findings imply that the visualization of decision-making stimulated awareness of the existence of those decisions. Both the quantitative and qualitative findings show signs that the intervention effected the self-regulating behaviour of students in the lower-classes of secondary schools. It is unlikely that the self-monitoring ability of students was affected, but very likely that there was an effect on the reflective ability. The self-reported score for this attribute did decrease, but this can be interpreted as a sign of more critical thinking. Overall the given timespan is too short to recognize any long-term behaviour changes. More research is needed on both the aspect of critical thinking and the durability of triggered behaviour changes.
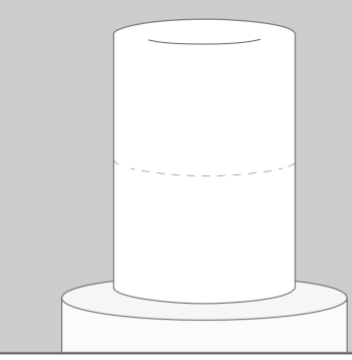
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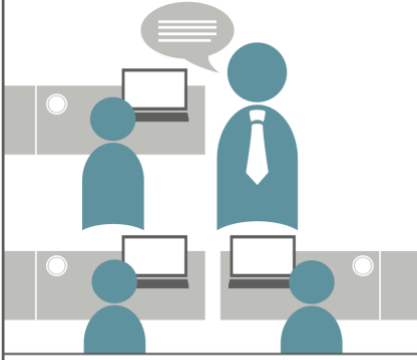5. Blanson Henkemans, O. A., van Empelen, P., Paradies, G. L., Looije, R., & Neerincx, M. A. (2015, May). Lost in persuasion: a multidisciplinary approach for developing usable, effective, and reproducible persuasive technology for health promotion. In *Proceedings of the 9th International Conference on Pervasive Computing Technologies for Healthcare* (pp. 49-56). ICST.

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**APPENDIX**

**Appendix 1 – Co-constructing Story Material**



* books, laptops, text balloons, computer screen and screen graphics are based on icons from © 500 vector mega icon pack from freepik.com.

* tie from the teacher is by © Roman J. Sokolov from The Noun Project.

# Vragenlijst voor aanvang

Binnen mijn project zal ik persoonlijke licht objecten in de klas plaatsen en het effect op het gedrag van leerlingen onderzoeken. Voor dat ik dit doe, zou ik graag een paar dingen weten over de huidige situatie. Er zijn geen goede of foute antwoorden! Het invullen duurt slechts vijf minuten en zou mij erg helpen.

*Deze vragenlijst is geheel anoniem, ik wil slechts een ding van je weten.*
Ik zit in klas: b1e/b3b/b3e (streep alsjeblieft door wat niet van toepassing is).

## Gesloten vragen
*Kruis aan in hoeverre je het eens bent met de volgende stellingen.*

| 1 = 'sterk mee oneens' en  5 = 'sterk mee  eens' (3 is neutraal) | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. Ik herwaardeer mijn ervaringen, zo dat ik van ze kan leren. | | | | | |
| 2. Ik probeer na te denken over mijn eigen sterke en zwakke punten. | | | | | |
| 3. Ik denk na over mijn acties en bekijk of ik ze kan verbeteren. | | | | | |
| 4. Ik denk na over vorige ervaringen om nieuwe ideeën te begrijpen. | | | | | |
| 5. Ik probeer na te denken over hoe ik dingen beter kan doen. | | | | | |
| 6. Ik controleer hoe goed het gaat, terwijl ik aan een taak werk. | | | | | |
| 7. Ik controleer mijn werk terwijl ik het aan het doen ben. | | | | | |
| 8. Terwijl ik een taak doe, vraag ik mezelf, hoe goed het gaat. | | | | | |
| 9. Ik beoordeel de juistheid van mijn werk. | | | | | |

## Open Vragen
*Probeer zoveel mogelijk op te schrijven waarom je iets doet, niet alleen wat je doet.*

Hoe bepaal je of luistert of doorwerkt tijdens de uitleg van de docent?
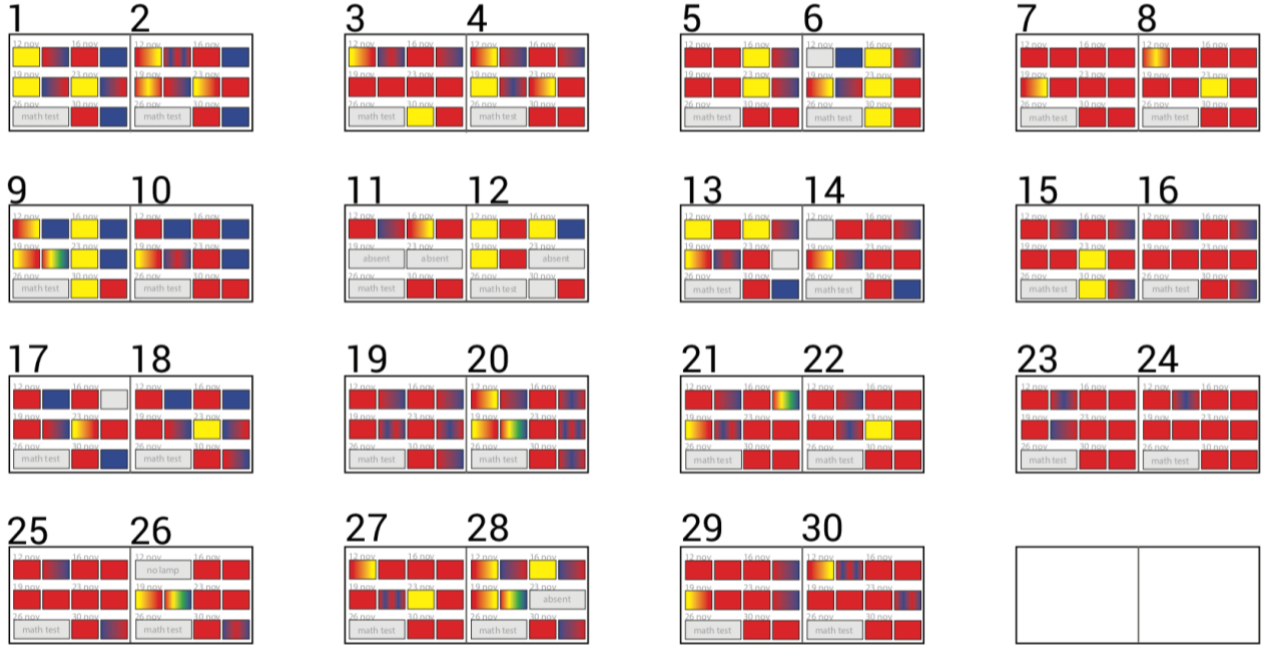_____
_____
_____

Hoe bepaal je of je alleen of samen werkt tijdens de (huis)werk tijd?
_____
_____
_____

Neem je de tijd om te reflecteren op hoe je gedrag je leren beïnvloedt?
_____
_____
_____
_____

**Bedankt voor het invullen van de vragenlijst!**

**Appendix 3 – Data Summary Observations**



First-class
Mathematics



Third-class
Biology

## 1
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 2
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 3
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 4
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 5
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 6
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 7
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 8
12 nov — 'D-toets' — 16 nov absent
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 9
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 10
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 11
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 12
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 13
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 14
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 15
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 16
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 17
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 18
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 19
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 20
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 21
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 22
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 23
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 24
12 nov — 'D-toets' — 16 nov absent
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 25
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 26
12 nov — 'D-toets' — 16 nov
19 nov — practicum — absent — 23 nov
26 nov — bingo — 30 nov

## 27
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

## 28
12 nov — 'D-toets' — 16 nov
19 nov — practicum — 23 nov
26 nov — bingo — 30 nov

# Vragenlijst na afloop

Onthoud dat er geen goede of foute antwoorden zijn zolang je maar zo eerlijk mogelijk bent! Het invullen duurt slechts vijf minuten en zou mij erg helpen.

*Deze vragenlijst is geheel anoniem, ik wil slechts een ding van je weten.*
Ik zit in klas: b1e/b3b/b3e (streep alsjeblieft door wat niet van toepassing is).

## Gesloten vragen
*Kruis aan in hoeverre je het eens bent met de volgende stellingen.*

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| 2. Ik probeer na te denken over mijn eigen sterke en zwakke punten. | | | | | |
| 3. Ik denk na over mijn acties en bekijk of ik ze kan verbeteren. | | | | | |
| 4. Ik denk na over vorige ervaringen om nieuwe ideeën te begrijpen. | | | | | |
| 5. Ik probeer na te denken over hoe ik dingen beter kan doen. | | | | | |
| 6. Ik controleer hoe goed het gaat, terwijl ik aan een taak werk. | | | | | |
| 7. Ik controleer mijn werk terwijl ik het aan het doen ben. | | | | | |
| 8. Terwijl ik een taak doe, vraag ik mezelf, hoe goed het gaat. | | | | | |
| 9. Ik beoordeel de juistheid van mijn werk. | | | | | |

## Open Vragen
*Probeer zoveel mogelijk op te schrijven waarom je iets doet, niet alleen wat je doet.*

Heb je het gevoel dat je door je lampje bewuster bent gaan kiezen?
_____
_____

Afgelopen les heb je ervoor gekozen om _____, hoe is je dit bevallen?
_____
_____

Als je een vergelijkbare situatie nog een keer mee zou maken, zou je dan hetzelfde kiezen of zou je een andere keuze maken? Waarom wel/ niet?
_____
_____
_____

Kijkend naar de keuzes die je hebt aangegeven, valt op dat _____, zou je deze informatie kunnen gebruiken voor toekomstige keuzemomenten?
_____
_____
_____
_____

**Bedankt voor het invullen van de vragenlijst!**

# Vragenlijst na afloop

Onthoud dat er geen goede of foute antwoorden zijn zolang je maar zo eerlijk mogelijk bent! Het invullen duurt slechts vijf minuten en zou mij erg helpen.

*Deze vragenlijst is geheel anoniem, ik wil slechts een ding van je weten.*
Ik zit in klas: b1e/b3b/b3e (streep alsjeblieft door wat niet van toepassing is).

## Gesloten vragen
*Kruis aan in hoeverre je het eens bent met de volgende stellingen.*

| 1 = 'sterk mee oneens' en  5 = 'sterk mee  eens'  (3 is neutraal) | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. Ik herwaardeer mijn ervaringen, zo dat ik van ze kan leren. | | | | | |
| 2. Ik probeer na te denken over mijn eigen sterke en zwakke punten. | | | | | |
| 3. Ik denk na over mijn acties en bekijk of ik ze kan verbeteren. | | | | | |
| 4. Ik denk na over vorige ervaringen om nieuwe ideeën te begrijpen. | | | | | |
| 5. Ik probeer na te denken over hoe ik dingen beter kan doen. | | | | | |
| 6. Ik controleer hoe goed het gaat, terwijl ik aan een taak werk. | | | | | |
| 7. Ik controleer mijn werk terwijl ik het aan het doen ben. | | | | | |
| 8. Terwijl ik een taak doe, vraag ik mezelf, hoe goed het gaat. | | | | | |
| 9. Ik beoordeel de juistheid van mijn werk. | | | | | |

## Open Vragen
*Probeer zoveel mogelijk op te schrijven waarom je iets doet, niet alleen wat je doet.*

Heb je het gevoel dat je door je lampje bewuster bent gaan kiezen?
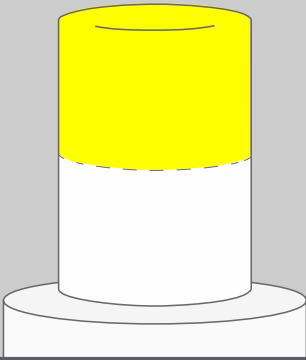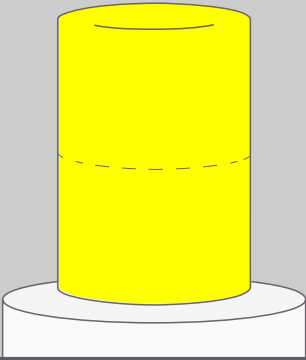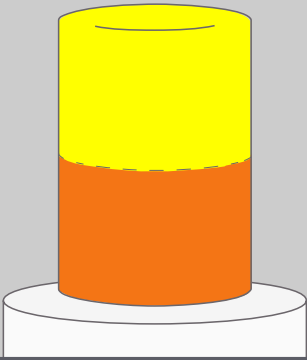_____
_____

Afgelopen les heb je ervoor gekozen om _____, hoe is je dit bevallen?
_____
_____

Als je een vergelijkbare situatie nog een keer mee zou maken, zou je dan hetzelfde kiezen of zou je een andere keuze maken? Waarom wel/ niet?
_____
_____
_____

Hoe vond je het om met een lampje je keuzes aan te kunnen geven (meeluisteren/ doorwerken & alleen/samen werken)? Op welke manier heeft dit je gedrag tijdens de _____ lessen beïnvloedt?
_____
_____
_____
_____

**Bedankt voor het invullen van de vragenlijst!**

**Appendix 5 – Future FireFly Applications**

| | | |
|---|---|---|
| Bovenkant geeft keuze leerling aan tijdens uitlegfase. Onderkant wordt niet gebruikt. | Bovenkant gelijk; Onderkant geeft de keuze van de vorige les weer. | Bovenkant gelijk; Onderkant geeft een samenvatting van vorige keuzes. |
| Bovenkant gelijk; Onderkant visualiseert het daadwerkelijke gedrag op dat moment. | Bovenkant gelijk; Onderkant kan in zes fases verkleuren op basis van gedrag. | Bovenkant gelijk; Onderkant geeft advies voor keuze op basis van 'prestaties'. |

**Appendix 6 – Statistic Analyses Split per Class**

*Reflection Scores (Q1-Q5)*

**Class = b1e**

**Group Statistics**

|  | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| Start | 28 | 3.8696 | .41440 | .07831 |
| End | 30 | 3.5400 | .45380 | .08285 |

**Independent Samples Test**

|  | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|
|  | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Equal variances assumed | .105 | .747 | 2.882 | 56 | .006 | .32964 | .11437 |
| Equal variances not assumed |  |  | 2.891 | 55.976 | .005 | .32964 | .11401 |

**Class = b3b**

**Group Statistics**

|  | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| Start | 27 | 3.3852 | .57241 | .11016 |
| End | 27 | 3.3315 | .71779 | .13814 |

**Independent Samples Test**

|  | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|
|  | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Equal variances assumed | .732 | .396 | .304 | 52 | .762 | .05370 | .17669 |
| Equal variances not assumed |  |  | .304 | 49.547 | .762 | .05370 | .17669 |

**Class = b3e**

**Group Statistics**

|  | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| Start | 25 | 3.4720 | .45417 | .09083 |
| End | 27 | 3.3037 | .58539 | .11266 |

**Independent Samples Test**

|  | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|
|  | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Equal variances assumed | 1.220 | .275 | 1.152 | 50 | .255 | .16830 | .14613 |
| Equal variances not assumed |  |  | 1.163 | 48.560 | .251 | .16830 | .14472 |

**Class = b1e**

**Group Statistics**

| | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| Start | 28 | 2.9241 | .69334 | .13103 |
| End | 30 | 3.0292 | .72790 | .13289 |

**Independent Samples Test**

| | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|
| | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Equal variances assumed | .027 | .870 | -.562 | 56 | .576 | -.10506 | .18695 |
| Equal variances not assumed | | | -.563 | 55.974 | .576 | -.10506 | .18663 |

**Class = b3b**

**Group Statistics**

| | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| Start | 27 | 2.8611 | .77934 | .14998 |
| End | 27 | 2.8241 | .99955 | .19236 |

**Independent Samples Test**

| | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|
| | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Equal variances assumed | 1.529 | .222 | .152 | 52 | .880 | .03704 | .24392 |
| Equal variances not assumed | | | .152 | 49.082 | .880 | .03704 | .24392 |

**Class = b3e**

**Group Statistics**

| | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|
| Start | 25 | 3.1300 | .71851 | .14370 |
| End | 27 | 3.1204 | .74476 | .14333 |

**Independent Samples Test**

| | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|
| | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Equal variances assumed | .038 | .847 | .047 | 50 | .962 | .00963 | .20325 |
| Equal variances not assumed | | | .047 | 49.909 | .962 | .00963 | .20296 |