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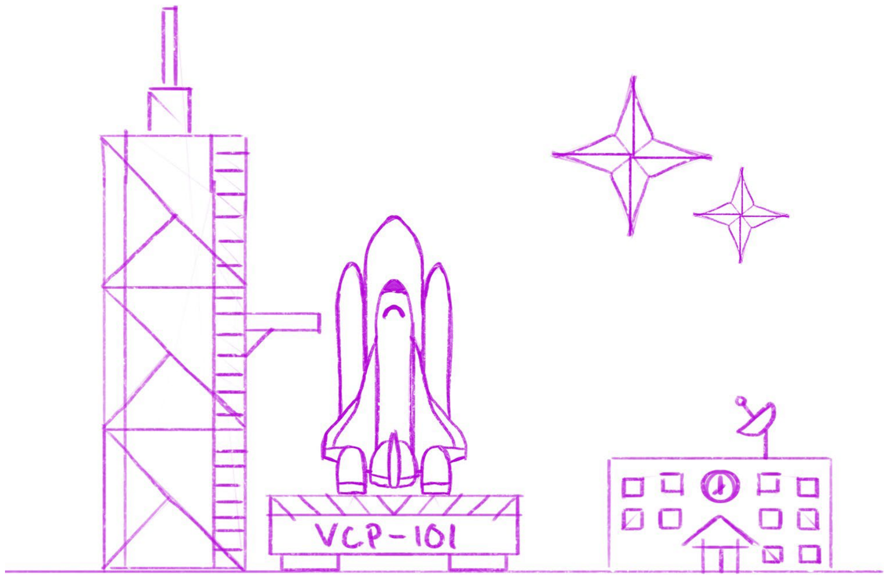

Value Creation Pedagogy in high-school STEM

Action Research on mission design for student motivation

Master's thesis in Learning and Leadership

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DEPARTMENT OF COMMUNICATION AND LEARNING IN SCIENCE
Chalmers University of Technology
Gothenburg, Sweden 2022
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Cover: Launch Pad and school as the space traffic control for the rocket illustrated in the book "The Value Creating Student" by Martin Lackéus (2022).

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Abstract

This master thesis investigates how to design missions for STEM-subjects in high-school based on Value Creation Pedagogy (VCP), with the intent to improve student motivation and learning using educational design- and action research based on Value Creating Research (Lackéus, Den vetenskapande läraren - en handbok för forskning i skola och förskola, 2021). The thesis provides a method and suggested workflow for design of Value Creating missions and several examples of VCP missions for STEM subjects at high-school level. The results include student responses, feedback from teachers and observations. The discussion raises challenges, opportunities, and implications for continued work with design and evaluation of VCP missions.

The results show that most students are unfamiliar with metacognitive reflection on their own learning and working iteratively with feed-forward. The students found the missions challenging, new and enjoyable. In addition to the student reports, notes and observations also show that students do not have the habit of recording their insights in text, find recipients motivating, and want to know why they are supposed to learn something. This implies that introducing a recipient, integrating real life skills, encouraging students to be aware of and elaborate on their own learning, working iteratively, and seeking early feedback will motivate students to learn more. The interested teacher can also save time by predefining a comparable assessment basis and helping students show what they have learned.

The value created in this study is primarily the method and considerations for designing value creating missions for STEM-subjects in high-school, and the lessons learned presented in the discussion. The collection of missions in Appendix M can also serve as a starting point for further studies and applications.

Keywords: STEM, motivation, value creation, pedagogy, action research, math, didactics

Acknowledgements

This project originated the 26th of October 2021. The last university course before the thesis had us searching for internships, and despite three weeks of proper applications the deadline came before any accepting replies. Almost. Deadline afternoon I meet the LoopMe team, and since then I have been creating value.

The first and for this thesis major thanks goes to Martin Lackéus, professor at Chalmers, author on Value Creation Pedagogy and supervisor for this thesis. Equal measures of entrepreneurship, engineering, and valuable insights on the challenges of leading and implementing change in the viscous world of education.

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Erik Söderberg, Gothenburg, May 2022

Glossary

Below is a list of terms, translations in *Swedish* and brief explanations of how these frequent terms are used throughout this thesis.

Term	*Translation*	Definition
Task	*Uppgift*	A student learning exercise without a defined recipient. Typically found in textbooks or tests. May be based on real life data.
Mission	*Uppdrag*	A student learning exercise designed to be Value Creating. Has a defined recipient for the students' knowledge learned and their artifact contributed.
Recipient	*Mottagare*	A person for whom the students' knowledge and contribution is valuable.
Contribution	*Bidrag*	The valuable product or performance of a mission as presented to the recipient.
Artifact	*Artefakt*	The overall product or performance created during a mission. Shows what the student have learned.
Formative	*Formativ*	In contrast to summative (after completion), formative refers to during iteration.
Tag	*Tagg*	A predefined concept or learning intent described by a few words designed to capture an experience from a mission. A mission may use and or correspond to several tags.
Emotion	*Känsloskala*	In the context of student reports, this refers to the reported emotion experienced about the mission. On a scale of -2 (displeased red emoji) in steps of one to +2 (happy green emoji).
Competencies	*Kompetenser*	Used as an umbrella term for skills, knowledge, abilities required to achieve a set goal. Attitudes is related as a foundation, but not strictly included.

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1 - Introduction

It is an ordinary day at school when students ask, "Why am I supposed to learn this?". A very relevant question that sadly does not always get the answer it deserves. "Because it is in the syllabus." is a common superficial answer. What the student may have trouble articulating is usually some levels of *Why?* deeper. "Why is it in the curriculum then?", "Who put it there?", and finally "For whom is this knowledge valuable?". This study aims to see how to design educational and value creating missions that answer these questions, hopefully leading to increased student learning and motivation. Phrased as a single and main question:

How to design Value Creating missions that increase student learning and motivation for STEM subjects at high-school level? [1]

Before the reader continues, a friendly reminder to read the Glossary for an overview of the terms and their definitions for this study. Recurring concepts such as *task* and *mission* are used differently in the text.

Value Creation Pedagogy

As outlined above, "Why learn this?". Even if the most subject- and pedagogy- competent teacher may teach well, it is ultimately the student who must want to learn. This study's attempt at creating that desire and motivation to learn is VCP. What is VCP then? Sharpening the answer to a pitch over the course of the thesis-work resulted in this story:

Students at vocational education programs are usually less motivated to study compared to university preparatory programs, especially in theoretical subjects. In contrast, their time spent at internships is usually very motivating (Lackéus & Sävetun, 2016). The knowledge gained there is very applicable, relevant, and important for both future employment and current supervisor. Rephrased in terms of VCP: The students' knowledge is also valuable for someone outside of themselves and their teacher. Both the student and the teacher are of course involved and interested in the student learning, but they do not always suffice to represent the world outside school. By isolating that recipient, it is possible to design educational content that shares the benefits of both motivation and learning.

This is central in VCP. By finding the recipient who has interest in, and can provide feedback on the students' contribution, the same positive effect can likely carry over to all subjects. Who that person is and what kind of value may vary. With school being an educational environment for the students, the focus is preferably not on only creating simply economic value. Social, environmental, or aesthetic values are also motivators. VCP is further detailed in the Theory chapter.

With finding a method for educational mission design as the primary goal, the recipients for this study are teacher and student roles. This motivates the following two questions to support the main question: *"How can Value Creation Pedagogy provide teachers with a complete grading material for STEM-subjects at high-school levels?"* and *"What exactly do students mean when they reflect on their participation in this study using*

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[1] *Hur designar man värdeskapande uppdrag som gynnar elevers motivation och lärande i STEM-ämnen på gymnasienivå?*

simple statements such good or bad?" The first support question reinforces the need to fit VCP missions to the curriculum, instructions, regulations and to give teachers participating in the study equivalent assessment basis for their time. The second aims to be that one step ahead and help students provide richer data. When students are asked to reflect over experiences, they often reply with simple statements such as "good", "fun" or "bad". The prepared reply would be "Good for you that it was good, but what exactly makes it good?".

Scope and Delimitations

The questions to study mention VCP, learning, motivation, STEM subjects at high-school level, grading materials and reflections. Additional definitions include location being limited to high-schools in Sweden due to language, curriculum and regulations, but thanks to online options not only to a single region or city. STEM subjects were chosen based on the engineering background of the project leader. To keep the STEM and high-school level comparable between schools, special or alternative education is excluded from this study.

2 - Theory

Examples of VCP in practice already exists (Marshall, 2019) (Amri, Adlim, & Nurdin, 2021), but as a defined semantic to explain and discuss that practice is recent and ongoing research. Drawing experience from double-loop learning, experiential learning and adding to recent original research (Lackéus & Sävetun, 2016; Lackéus M. , 2016) showing VCP improving student motivation, there are learning theories and results supporting the model in development. A section for handbooks and guides on best practices reinforces the support.

Value Creation Pedagogy

Value Creation Pedagogy is a pedagogic model stemming from Entrepreneurial Learning, with the focus being student motivation through finding for whom the knowledge is valuable and following through by actually creating that value for the recipient. *"learning-through-creating-value-for-others"* (Lackéus, 2022). By having a real recipient who cares about and can give feedback on the performance and result, the question of why to do or learn something should have been given a personal answer. VCP is described in full detail in "The Value Creating student" by Martin Lackéus (2022). In the same book, the full definition is cited: *"Let students learn by using their current and new competencies to try to create something, preferably new, of value for at least one external stakeholder outside their own group, class or school."* This definition is further explained in a table from the same book, reproduced on this page to give the reader a more complete introduction.

The Value Creating student - Table 1.1, p.31, (own translation):

Let students learn	The main purpose is learning, even if students often perceive it to be the creation of value for others
by using their current and new	Students may apply both existing and newly acquired competencies
competencies	The exercise aims to develop both knowledge, abilities and attitudes. The term competencies is used as an umbrella.
to try to	It is the attempt that counts. Even if there is no resulting value there can still be lessons learnt from the process or failure.
create	This is a creative exercise. The student is expected to create something previously not existing.
something,	The result being some physical (hands on), intellectual (recorded ideas) or cultural (social) artefact.
preferably new,	New is desirable but not mandatory. New for the student or new to the world. The newer, the more emotional impact.
of value for	The result needs to have some appraisable value and is preferably also appreciated by the recipient.
at least one	At least one external that can give feedback about the value contributed for them. Can also be animals/plants.
external recipient	The more external the recipient or stakeholder, the more impact of the exercise, but also the higher emotional stakes and complexity.
outside their own group,	A first step is often to create value for other students in the class
class	The next step is outside the own class, but still within the safe boundaries of the school.
or school.	The most impact comes from involving recipients outside of school, but also increases stakes and complexity.

An example of how to translate the definition to missions is found in the Method chapter, with further examples of complete missions given in Results and Appendix Missions. VCP in subjects outside STEM show increased student motivation (Lackéus & Sävetun, 2016; Wiman, 2018). There are also studies on Project based learning showing positive and significant improvement in student motivation (Rocker Yoel & Dori, 2022; Amri, Adlim, & Nurdin, 2021). It is likely that the missions in this study will also show similar trends.

Learning theories behind VCP

Double-loop learning (Argyris, 2019) models learning as a cycle similar to action research, stepping through assumptions, actions and results. The double refers to changing the underlying assumptions, why, instead of the single-loop action of what and how. As outlined in the introduction, students do ask why. According to Argyris model, strong learning or change is achieved when targeting the why. Students seem aware of this, illustrated by a stylized thought: "From my understanding of how my teacher presented this, my initial assumption is that this is without value or purpose, and therefore I am asking why we students are supposed to learn this, in hope of finding value and motivation to help me learn. I am essentially asking for help with the double-loop. It is in the curriculum for a reason and will likely show up on a test or exam, so I might as well try to enjoy the process of learning." With VCP providing a personal why, the motivation for change overlaps.

Another learning modelled as a cycle is experiential learning (Kolb, 2015; Beard & Wilson, 2013). In four steps - active experimentation, concrete experience, reflective observation, and abstract conceptualization. Again, similar to action research, with learning as a cyclic process. VCP does in theory not necessitate experiential learning, but benefits from it in practice. To create value, one needs to plan what to create, create the contribution, request feedback on value created and often reiterate to improve.

Entrepreneurial learning as a term is less defined in its use than the mentioned models above but is most often interpreted as how and what entrepreneurs are learning (Nogueira, 2019). Other studies *"[...] have reinforced the understanding of Entrepreneurial Learning as: (1) an individual-level phenomenon; (2) an experiential learning process involving: (2a) entrepreneurs' learning styles; (2b) learning from failure; (2c) the learning embedded in the pre-entry experiences of the entrepreneur; and (2d) vicarious learning."* (Nogueira, 2019) There are also links to double-loop learning, the individual reflections as self-regulated learning, and social learning as a team. There seems to be no disagreement on that entrepreneurs need to, and do, learn, but what defines entrepreneurial learning is still at low resolution. Entrepreneurial as in venture creation, having a customer, a product and creating economic value as a platform for learning is independent on the definition being general (Santoso, Junaedi, Priyanto, & Santoso, 2021).

Good practices for teaching and learning

With the intent to provide a guide on how to design value creating missions, this section focuses on literature providing good practices, opportunities, challenges, implications, and applications for specific subjects. Most references are titled Handbooks for designing educational materials using various methods and points-of-entry.

The most complete book for this purpose was "A Handbook for Teaching and Learning in Higher Education" (Marshall, 2019), containing many relevant chapters both for general pedagogy and for STEM. Some of the steps mentioned for success as a university teacher are listed here: Organize to encourage sharing of local initiatives, enable knowledge transfer and give room for creativity. Involve the academic staff in teaching. Have material prepared and finished in advance. Make time for appraisal, personal review and development. While aimed at university, these tips parallel this study preference for innovative research, on location, with prepared missions and feedback.

Chapter 5 and 6 mentions several relevant terms for discussing VCP. Critical thinking in the disciplines and life skills are two expected learning outcomes from higher education. Graduate attributes that need practice and often a more student-centered learning approach. The concept of Legitimate peripheral participation also highlights the excluding view on students as less capable. How else but practice and participation should a novice integrate to become a competent community member?

Educational intent, the answer to why are we doing this and what is to be achieved, is another. The knowledge, attitudes and skills achieved by a performance under certain conditions and criteria reached are again reflected in the method for this study: Report, emotion and tags following mission instructions, feedback and course competencies.

Learning-oriented assessment (*for* and *as* learning), feedforward, and formative feedback is also encouraged. The Chapters 15-17 on STEM recommend interactive lectures for larger groups, and for smaller groups problem-based learning, lab, fieldwork, simulations, and visualisations. Both formats can integrate reflective self-assessment, peer-review, and metacognition during the process.

At page 251 in the same handbook is Case study 17.1 - projects that benefit the community. That course has been recording questionnaires from cases over several years, and results show there was significantly higher satisfaction regarding the cases after introducing social motivation. In VCP-terms – by introducing a recipient.

Another book with similar focus to this study is "A Companion to Interdisciplinary STEM Project-Based Learning" (Capraro, Whitfield, Etchells, & Capraro, 2016), a compilation of several larger examples for project-based learning in STEM made with the intention provide students with meaningful answers to "When am I going to use this?". The projects follow a template that clearly presents what the student is expected to learn, test, or perform, with supporting teachers notes and project intents. These projects and tasks can serve as inspiration for potential VCP missions and recipients.

A supervisor in Vocational Education Training (VET) is an existing role similar to a VCP recipient. What can VCP learn from VET supervisors? VET is often regarded as separate in terms of status and usefulness for higher education (Guile & Unwin, 2019). Another angle is the potential for VET solving social or economic problems by bridging employers and employees. The former contrasts with the often teacher centered approach, the latter with school as a primarily educational institution. If instead rephrased as opportunities: life skills in working between operational and management levels, and motivation from helping others. The term "higher apprenticeships" are sometimes used to describe these positive translations when applied to more academic environments.

Milton (2010) gives two relevant quotes about learning from experience and strong emotions: "Learning from experience is the most basic of human activities." (p.1) and "It is easy to learn from experience, if the experiences are powerful enough. You only have to put your finger in the toaster once, to know that it is a bad idea." (p.1) Two relatable quotes about lessons identified and lessons learned. While pain from a hot toaster is not the emotional response desired in high-school, a similarly intense positive or negative emotion can also bring powerful learning. From only a single iteration of trial and error, most children do not repeat the toaster experiment.

To succeed in trial and error, trial and success or other inquiry-based learning, the reflection that leads to change is mandatory. “A lesson is truly learned when we modify our behaviour to reflect what we now know.” (Bailey, 2005) as cited in (Milton, 2010) With the teacher as a guide, learning from the previous mistakes of others also becomes easier.

The teacher as a guide usually implies that the teacher has a plan for the learning intent. Especially for the more open and student-centred formats of Case, Problem-based or VCP learning. A starting point for designing these is an “authentic problem that is relevant to the learner” that is problem-focused, student-centred, self-directed and self-reflective (Jonassen, 2010). The motivation for this kind of situated learning comes from using real world problems and context together with anchored instruction usually told as a narrative story. The storytelling for Case and PBL usually introduces characters invested in the problem being solved, whereas VCP directly involves a real recipient.

PBL situates the student in a cognitive apprenticeship (Jonassen, 2010), where the novice learns the tools in a close to real-world context. The teacher’s (master’s) role becomes to explain what is behind the master’s decision making, letting “students learn to think and perform like masters.” (Jonassen, 2010). One of the master’s tools are likely information-searching skills. PBL provides opportunity for finding information, but students may need to practice this and be given scaffolding until able to do so on their own. Worked examples can serve as an initial and well scaffolded start, enabling more open and complex cases.

Helping students reflect on their learning is one way to let students learn to think and perform like masters. Metacognition is a skill that can be trained. One method for this is Action Learning defined as “… a continuous process of learning and reflection that happens with the support of a group or ‘set’ of colleagues, working on real issues, with the intention of getting things done.” (Brockbank & McGill, 2003). Students helping each other put their learning in words is one application.

Returning to experiential learning, an experience without meaning or challenge triggering the steps in the learning cycle is likely not educational. “A much more effective and long-lasting form of learning is to involve the learner by creating a meaningful learning experience.” (Beard & Wilson, 2013)

With many good practices to apply, and examples to use and develop, this study has a solid foundation for designing its method and value creating missions.

3 - Methods

Traditional scientific research dependent on few very controlled variables contrasts with the generally not-so repeatable environment in schools. If the focus is rigor alone, the relevance for the classroom may be lost. On the other end, subjective truths found by interviews and observations may fail to translate between situations (Lackéus, 2021; Reeves, 2011). A commonly used method for research in educational settings to address the issue of rigour versus relevancy is Action Research (Willis & Edwards, 2014; Andrew, 2010; Bradbury, 2015). A select number of actions are performed in various combinations and their impact or lack thereof are evaluated. The attempt is preferably repeated multiple times with multiple actors. To further improve both rigour and relevancy, use both quantitative, qualitative, deductive, and inductive methods (McKenney & Reeves, 2019). Examples of quantitative data could be observations, forms, or test results. Qualitative similarly text or discussions. Deductive methods use existing theory to formulate and trial a hypothesis, while inductive methods seek to create new models. If using all methods iteratively the overall method becomes mixed and abductive.

This design study is based on VCP lesson planning and experiences recorded according to Action Research (Bradbury, 2015), with the most accurate title or category being educational design research (McKenney & Reeves, 2019; Reeves, 2011). The student data was gathered using a cloud service called LoopMe. The app interface for students included mission description, instructions, a free-text response field to reflect and answer in, optional file attachments, an emotion, and tags. Tags can be described as checkboxes with short descriptive statements, coding for a deductive prediction of experiences and desired learning intents for the mission.

The data was categorized and summarized by thematic analysis (Andrew, 2010). In addition to the data from student responses, timelines and observations from the classroom, complementary notes from meetings and communication with teachers and students were also recorded. The educational design research method used for this study is elaborated in table 4.1 from (Lackéus, 2021) on the next page. Keywords elaborated in the table include longitudinal, experiment, survey, action research, grounded theory, mixed method, abductive, pragmatism and critical realism.

Value Creating Research

Table 4.1, p.77, Overview of VC Research as research method. (own translation)

Overarching theoretical frameworks, "LOGIC"	**Clinical research** – We learn by trying to create value for others **Pragmatism** – We ask ourselves what works for whom, when, how and why **Critical realism** – We are looking for weak cause-effect-patterns at high resolution **Action oriented collective learning** - Many test the same ideas **Abductive** – We apply both theory and practice with a systematic approach **Emotions** – We perform actions that will trigger an emotional response to record
Working models on a strategic level "MODEL"	**Working hypothesises** – We formulate hypothesises about what can help others **Actions** – Teachers study with and on each other by missions **Experiments** – We test in a live classroom if and how it works in practice **Design principles** – The beginning and the end of the research journey **Fine-grained** – We mix theory and practice frequently, preferable every week **Protocol** – We decide what everyone shall test, by which deadline and keep protocol **Written** - We record all insights and feedback in text **In good faith** – We keep confidentiality by only having a few reading all reflections
Practical data recording methods "TACTIC"	**Recording Experiences** – Everyone continuously submit forms in real-time **Connecting action and reflection** – Every reflection is connected to an action **Longitudinal research** – We gather data over a longer period of time on a weekly basis **Deep reflection** – We engage in deep reflection after each performed action **Mixed method** – We record both reflections and numerical estimates each time **Recording Emotions** – We always estimate the overall emotion from an action **Coding effects** – We try to predict effects by using tags, allowing everyone to code **Feedback** – All participants receive feedback from the project leaders
Practical data analysis methods "TACTIC"	**Formative analysis** – Important insights from a work in progress is continuously recorded **Mixed analysis** – Numbers guide the searching for trends in recorded texts **Graphical analysis** – Matrices and diagrams provide useful overviews of the data **Collegial analysis** – Project leaders summarize to invite all participants in the analysis **Anonymous sharing** – Especially interesting responses can be shared anonymously **Cause-Effect-Analysis** – Deep analysis of when, how and what causes observed effects **Revision of design principles** – Findings from the analysis becomes the basis for revisions

The four categories sort the parts according to their level of abstraction or concretization. *Logic* relates to research philosophical questions; *Model* shapes the principles that connect *Logic* and *Tactics* to practice, and *Tactics* represent concrete tools and techniques. (Lackéus, 2021) By as far as possible incorporating this wide range of guiding principles in the method of this study, the goal is to create guide or handbook contributing to both practical relevancy and theoretical understanding. A definitive best practice for VCP in STEM might be too early to claim, but lessons learned and their implications can hopefully be of use.

VCP Workflow

With the goal of designing and evaluating a method for mission design, a draft for the workflow creating missions was made and iterated throughout the study. Figure 1 below shows the suggested steps, which are further described below. The figure uses linear equations as an example but its workflow was applicable for the other subjects and topics in this study.

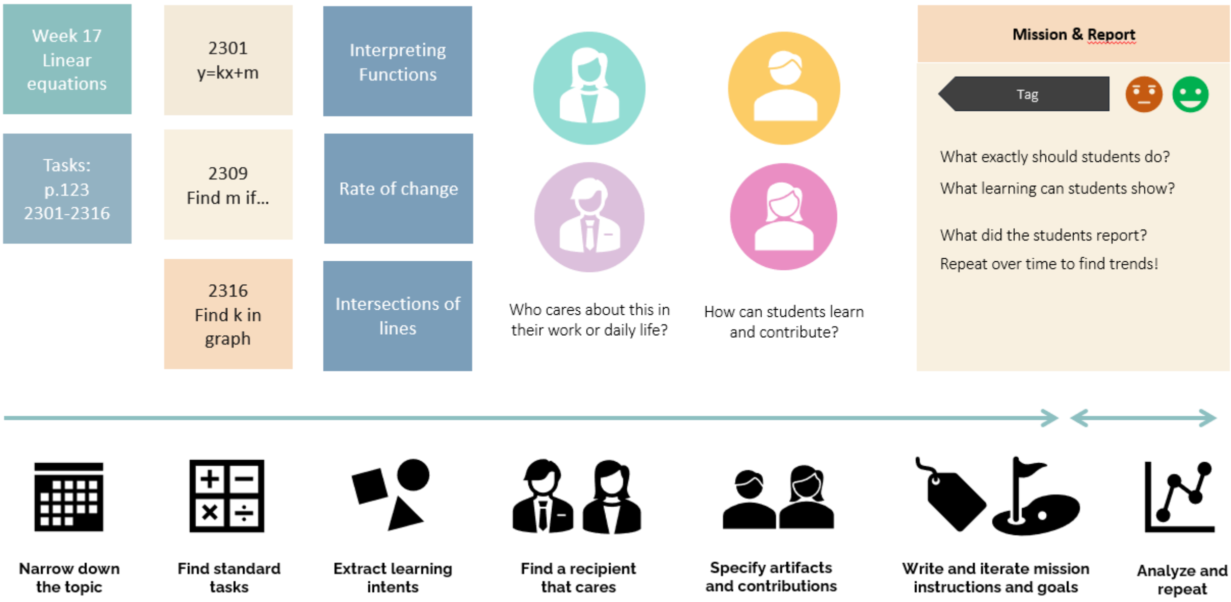

Figure 1 – A schematic overview of the workflow used and iterated to design value creating missions. In chronological order from left to right: Narrow down the topic based on the teacher's calendar and plan. Find existing tasks for that topic. Identify the learning intent in those tasks. Find a recipient that cares about the students learning for that topic. Specify how students can show what they have learned and contribute value for the recipient. Write instructions, tags, and goals. Analyze and give feedback on the student reports. Repeat the whole process over time to find trends.

To narrow down the topic, one of the first steps after introducing the project to an interested teacher, was asking them to provide their course plan and topic for the weeks when the project would take place, illustrated by the first column in Figure 1. The second step was to find standard tasks for the topic. These were usually included in the course plans from step one. With the recipient likely being more interested in the competencies learned than the tasks themselves, the idea leading to step three was that the recommended tasks were already selected to cover the learning intents for the topic. By extracting the learning intents, it was easier to find a recipient who cared in step four.

In step five, the learning intents were matched with the recipient's interests. This specified what artifacts students were to produce to show learning and contribute value. With a specified artifact as the goal, the next step was to write instructions for how students could create it. Based on the instructions written so far, a prediction of what learning students may experience from the mission was made and tags were created to capture those experiences. The instructions and tags were then iterated with the teachers to ensure that there was opportunity to show the intended learning, and that the instructions and difficulty was reasonable.

The teacher and project leader both supported students in the classroom, and as soon as the first students had completed a mission, the teacher could provide formative feedback on their written reports. By repeating the steps, it becomes possible to analyse and evaluate performance on both individual and group level over time. Considerations for the design process and finding a recipient is further elaborated in the following sections.

Finding value in mathematics

A quote from a student during a lesson in this project pinpoints the need for value in mathematics: *"Who cares about the linear equation?"* A perhaps common question that if paraphrased in VCP terms would be: "Who cares about *my knowledge of* the linear equation?". L inear equations or mathematical models in general are tools used to describe and predict. This may make it difficult to find a recipient for simply the tools themselves. While not worthless, it is rather the application and skilled use of these tools that can create value for a recipient. An analogue in language is grammar, which in itself is square rules, but necessary to convey sensible information or write a bestseller. With that in mind, the mission drafts for mathematics often focus on deconstructing and explaining a concept or guiding the recipient in tool usage.

To give one possible answer to the question of linear equations: Anyone managing an inventory could have use for linear equations. To keep a stable stock, rates k and current supply m need to be known. These values are often known by experience but could be made helpfully explicit with knowledge of the linear equation. See Appendix Missions for more math examples.

Finding value in nature sciences

In the same spirit as the quoted student, the project leader wants to make a point: *"Who cares about my knowledge of acid and bases, magnetic fields or history of technology?"*. While the science, technology and engineering subjects may be closer to application than pure mathematics, the recipient for whom the competencies are valuable is not always obvious. While high-school level education in STEM is a step further than what the majority of the population has studied, it is also not yet at the level required for most industrial or academic applications. A professional chemist probably cares about students learning about acids and bases, but most likely also already knows everything a student could contribute. A person who has had little to no chemistry education may not care for or lack the framework to grasp the level the chemistry novice is at. Similarly for the other scientific fields.

That is not to say that high-school level STEM is in a useless limbo. Interpreting results, rather than optimizing or predicting is one example of where the novice level can be valuable. Technicians, operators, or similar end-users that have not studied high-school STEM themselves can be caring recipients, helping students see their theory in application while also gaining understanding themselves.

Feed-forward and working in iterations

A critical skill in any scientific area is being able to communicate and explain to the public, much like any teacher. Students are not teachers and have separate responsibilities, but can likely learn much by teaching others, even as novices. Peer-review, feedback and designing instructions are all situations where students can have each other as recipients, hopefully creating win-win situations. Hopefully, as there are some pitfalls to avoid:

Peer-review is often summative rather than formative. Feedback is often more formative, but also less precise. Ideally the students learn by helping others learn. The less-than-ideal scenario is making students fail due to poor contributions of other students. This can be prevented by early feedback, working iteratively in small steps, and making sure that there are no critical dependencies for individual students' opportunities to show learning.

If this approach has some potential risks, why encourage it? Trial and error can bring strong learning (Milton, 2010). By designing the missions to enable and promote students seeking early feedback, potentially only soft failing early instead of harder and later, time spent on reworks can be minimized and the learning strengthened.

Effort required for the recruitment of teachers

With the aim of cooperation with about ten teachers, all channels available were used, including phone calls, mail templates, social media posts, RSVP's, FAQ, and applications of interest. With many schools still recovering from sick leave and online teaching during covid-19 this spring of 2022, this step required contact with an estimate of about 800 teachers. To help put the effort in numbers: The total count reached for this project is estimated at about 800 teachers, with a final count of 9 participating. The 800 is based on about 150 direct calls to teachers and principals, about 200 teachers replying to mail, 150 through supervisor's and MeAnalytics's network, and the rest indirect through forwards and social media groups.

During the recruitment, contacted teachers often asked for examples of missions and how participating in the project would affect their calendar. The work spent preparing missions was helpful as both exercise to get more acquainted with VCP and to have material prepared for curious teachers.

These tasks usually hold more flavour than simple procedure, but the question of how to motivate a student to perform it remains. A glossary reminder - The term task is used in this study referring to learning exercises where the assignment often has real life relevance or use and provides good practice but does not include the VCP recipient and reflections. With VCP as the suggested answer, the next but sometimes not obvious step was to find and figure out how to involve the person for whom the knowledge gained in the task was valuable. This is where the task turned into a value creating mission. Examples of VCP missions are found in Appendix Missions.

Planning, presenting, and practicing VCP with teachers

With both the data recording app and VCP being new tools and concepts to introduce to teachers and students, two separate workshops at about 30 minutes each to explain and explore with the participating teachers was held. Teachers rarely had time for more. As many of these workshops were held online, a test mission for teachers and students to explore the interface was also prepared to keep most of the workshops' time spent practicing and exploring together.

These workshops were also an opportunity to discuss and help teachers set student expectations. With the fear of students dodging the missions, having the teacher also stating the importance was requested. To further encourage students, we explicitly stated that while the format might be different from the average class, it will nevertheless be an opportunity to learn and provide assessment basis. To help students, a request to try small steps and ask for early feedback was also stated.

Since the participating teachers' topic for the relevant weeks was known, the actual mission drafts had been iterated with feedback from the teachers, as outlined. To keep the missions comparable and further explain VCP for the teachers, refining drafts for the missions was also part of the workshops. Dialogue about the missions and surrounding logistics, primarily by mail, was maintained with the teachers until the date of visiting the classroom and students performing the missions.

Another benefit of the many digital platforms available was not being restricted by geography. Introducing the project, VCP, supporting the students navigating the app and explaining missions was done both on location and by video meeting, sometimes both. With the usual teacher also present in the classroom to lead and support the students, some of the difficulties of online teaching was mitigated.

Feedback to participating students and teachers

To help and encourage students learning and reflecting, all student responses were given feedback following a template of thanking the students for their participation, providing constructive criticism, and asking a question for the student to reflect on. The hope of doing this in collaboration with teachers sadly did not fit the teachers' schedules. The feedback with and from teachers was more of a dialogue during and after the lessons, which shaped the final missions and method iterations presented here.

Analysis of results

The data provided by students was exported to spreadsheets. To identify potential trends, thematic analysis was used to code the students' written reflections and answers. These categories were then compared to the corresponding tags and emotion, using Pearson's correlation as described in (Wilcox, 2011, pp. 243-263). The assumption here was that the students using the same tag or emotion were likely to have written similar reflections. With the intention to measure students learning per mission, a correlation matrix for tag usage and emotions was used to examine if there were certain tags correlating to the emotion reported, or if some tags were compounded with another tag.

Action research and tags make deductive data. With tags and questions being predefined there was risk of not capturing all the experiences and effects. To mitigate any unexpected blind spots, support, and enrich the students' data, notes, quotes, and discussions from and with teachers were recorded during the project. There was also the tag "Misc/Other" and room for elaboration in the text-replies.

Tags used

Tags should preferably be as self-explanatory and clear as possible. The tags that were used are presented here with a brief explanation where needed. Some are similar, but with nuances to differentiate.

Table 1 – An overview of the tags available for the students when reporting their missions.

Tag (Eng)	*Tagg (Swe)*	Explanation
Explanations helped me understand	*Förklaringar hjälpte mig att förstå*	Separate from instructions, the interactions and feedback between students and or recipient.
I could explain for someone	*Kunde förklara för andra*	Anchoring the curriculum and creating value for the recipient.
Found the information I needed	*Hittade informationen jag behövde*	While most of the information should be provided in the instructions and previous lessons, this hints that the students may need to find new information on their own initiative.
Meaningful	*Meningsfullt*	Did the student find any purpose in performing the mission?
The recipient cared about my contribution	*Mottagarenbrydde sig om mitt bidrag*	Did the student ask for the feedback required to evaluate this? Another hint at taking initiative.
The goal of the mission was clear	*Målet med uppdraget var tydligt*	The instructions and expectations were clear. Focus on the goal and not the process of getting there.
Easy /Challenge/ Difficult	*Lätt / Utmaning/ Svårt*	Generally perceived difficulty level of the mission.
Misc / Other	*Övrigt / Annat*	Catch-all for what is not included in other tags.

Missions

Here Table 1 presents an overview of the missions students performed during lessons. Complete mission details are given in Appendix M.

Table 2 – An overview of the missions students performed during lessons.

Mission Title	Overview	*Intended recipient*
Reflections – Value Creating Pedagogy	Reflections about missions, format and overall experience.	*Project Leader*
Stochiometry: Designing Laborations [1]	Designing a short lab instruction for classmates, with the intention of using students' contributions during an actual lab. Peer-instruction with early feedback and iterations.	*Classmate*
Functions: How many? [2]	Translating math used by 3-year-old children to formulas. Asking children to count, add, subtract and compare and represent their answers in written math. Discussing with teachers on how to encourage playful math.	*Children & Preschool Teacher (VET supervisor)*
Functions: Linear logistics [2]	Modelling inventory rates using linear functions. Visualizing values important for business revenue. Discussing with relevant persons how mathematical models can help employees prioritize work.	*Logistics employee (VET supervisor)*
Functions: Tools of the trade [2]	Janitor equipment at school may include thermometers, gages, levels or tape measures. Logging in- and output values in tables and describing simple functions connecting the two.	*Janitor or similar (VET supervisor)*
Functions: Limitless exponentials [2]	Finding exponential systems and describing their real-world limits. Populations being limited by food as one example. Define how exponential differs from linear or quadratic.	*Friends or family outside school*
Statistics: A reliable study [3]	Recording random data from dice in tables and analysing results to separate statistical terms from each other. Discussing and writing what makes results reliable, identifying trends, risk or chance and repetitions.	*Classmate*
Statistics: Hands and happenings [3]	Recording random data from rock-paper-scissors in tables and analysing results to separate statistical terms from each other. How data can be used to visualize behaviour. Perception leads to misinterpreting data. Dependent or independent events.	*Classmate*
Statistics: Methods for mean and median [4]	Approximating source data from trends showing means using boxplots. Drawing implications from differing mean and median. Using basic computer tools to help in interpreting graphs and labels, presenting and motivating data.	*Classmate, other students*
Reflections – Value Creating Pedagogy – extended [5]	Reflection about mission, format and overall experience. A few extra questions specific to their project.	*Teacher and Project Leader*

1 - Kemi 1 – Chemistry, first course, Nature Science program,
2 - Ma1a – Mathematics, first course, Vocational program
3 - Ma1b – Mathematics, first course, Economics program
4 - Ma2b – Mathematics, second course, Economics program
5 - Teknik 1 – Technology, first course, Technology program

4 - Results

In this chapter the results from students reporting on missions, notes from discussions with teachers, and observations are presented. Translations are kept as closely [sic] as possible. A selection of primary data is found in Appendix Data.

The student reports are summarized and sorted by mission. This includes a brief overview of the class, subject, mission focus and description, a selection of representative student quotes, and observations from and about the classroom.

Reports sorted by tags and emotion

The summarized data from all student reports, including emotion and tags, is presented in Appendix R. Overall tag usage shows most tag frequencies land somewhere in between 10-25%. The difference between classes and missions are rather small, with only tags for difficulty level varying significantly. The tag “I could explain for someone” got the lowest frequency overall. The largest difference between classes is for the “The goal of the missions was clear” where Teknik 1 that had been working on their project for some time previously tagged 58%, and the others average at 10%. The average difficulty reported was at challenging. Not all students tagged any difficulty level.

Looking at statistics between tags and emotion in a correlation table shows: “Difficult” correlates inversely to emotion (-0.41, p≈E-10) and about (-0.17, p≈E-2) with the other tags. Too high mission difficulty makes unhappy students that do not elaborate further. The most positive tag was “The goal of the mission was clear”, which averaged (0.22, p≈E-5) and with “The recipient cared about my contribution” (0.35, p≈E-7). Students that know where they are heading also have the foundation for a recipient in mind.

When sorting reports by emotion there were general patterns to categorize. Student reports with very positive emotion mentions the keywords good, new and exciting. Many students report having social fun working in their group, as illustrated in the quotes below:

> *“It was good and fun with some variation to the lessons.”*

> *“I think this has been more fun that doing more theoretical tasks where you are only doing it for the grades. I therefore feel more engaged in the project.”*

> *“We learned to cooperate a lot in a group”*

Student reports with positive emotion mention understanding instructions with some effort, the format being different, recording data and analysis. This category had the most reflective answers. Three representative student quotes are shown below:

> *“I learned to take notes for a study and to analyse the results. It was fun to do something new and different from the usual.”*

> *“We learned to log statistics and used new words. We also argued that the test was not reliable. It was fun but instructions were a bit difficult.”*

> *“It was ok, I understood the task today and found some correlations but did not quite see the purpose of the task”*

Student reports with neutral emotion performed parts of the mission but did in general not understand why. Another three quotes from this category that mention the common action without understanding or reflecting are cited below:

> *“I don't know. I did not quite understand the task so I'm not sure if I even did it right. However it was fun and interesting to*

discuss the different graphs with my supervisor"

"Did not understand the purpose of what to do with the task"

"I like the idea for this project, but for me who does not like technology that much, this task becomes difficult because there a lot of technical stuff."

Student reports with negative emotion found the mission difficult or did not understand instructions. The pattern of stating emotion and then cause recurs in many of the responses to this category. Three quotes are given below:

"I think it was a hassle and complicated and I got demotivated when things did not work and I did not understand since I became irritated and bored then. I would have learned better by the usual maths. However it was good to have some variation in the tasks and working with others."

"I think learned about how to use the Paint function on my laptop. Also to use it for math in a new way."

"I learned a little of what exbonentioal means and that it is a stupid word because it cant be written orr read properly."

Student reports with very negative emotion are generally shorter. Many mentions difficulty, then reject and eject. Three common and colorful quotes for reference below:

"I did not like it one bit because I think it is a braindead task that does not help anyone"

"Unclear, we did not understand why we did this"

"Difficult"

Overall, the correlations between difficulty, clear goal and emotion are reinforced by the student text responses. If they report difficult, they are also likely unhappy. If they report understanding, they are instead likely to also mark positive emotion.

Student reflections

When asking the students "How can you show the teacher what you have learned?" the overwhelming majority instead replied to the question of *where* or in *what situations* they could show what they had learned. One typical and representative student answer was: *"I can be active during lessons and participate in discussions. Ask and answer questions and perform during exams and tests."*. In the total of 80 answers, about 40 students mentioned exams, tests, and tasks each, follow by a few of each; lessons, hand-ins, and discussions. Only two students answered the original question of *how* with the more reflective "use what I have learned" and "explanative text" respectively. Students were not used to reflect on what they have learned but were very aware of the deadlines where they are supposed to show what they have learned. To the remaining 78, the feedback was: "What exactly is it that you do during tests etc. that shows what you have learned?". No students replied further, likely due to the easter holidays after the project.

The question "What makes you ask why you need to learn something in school?" assumed students do ask. By own experience and the results here, they do. Of the 80 answers total, about half of the answers include: that the topic feels unnecessary, to find relevance, to find future uses, and to connect the current topic to previous knowledge. Six answers mention having no reason to ask, and another four try to find their own answer instead of asking. Another student quote summing the gist quite well: *"I ask in a mostly ironic way if we receive a difficult, repetitive or boring task. I know it likely is good to learn whatever it is and that I don't really have a choice."*. Students want to find meaning but resort to submitting to authority in lack of an answer.

Few students gave reflective or descriptive answers to the follow-up question: "What do you think you have learned by doing this mission?" asked as a self-assessment after each mission. A note on that this is what they think, and not necessarily what they have shown or given correct answers to. A lot of answers were simply repeating what they had done without mentioning skills or knowledge. The mentioned keywords in the about 50 of 150 descriptive answers were nothing, analysing data, use cases and project organisation. Three representative answers; *"Not so much, I already knew everything."*, *"We learned to read diagrams and analyse data."* and *"Did not really understand the purpose or what to do."*. Like the answers to how to show learning, metacognition on learning outside tests is also unfamiliar. Feedforward given to those answers was "What do you include in 'everything'?", "What tool or method did you use to read diagrams or analyse data?" and "What in the instructions or explanations was missing that if included would have helped you understand?"

The Table 1 below shows answers to the question "What's your opinion on working in VCP format?" categorized by class. With only Teknik 1 approaching Value Creation as described and intended, the question is less relevant for VCP, but can still give some insight on the general and initial student attitude and experience. Some reports include multiple categories per report, giving a sum greater than total for some columns.

Table 3 - Answers to the question "What's your opinion on working in VCP format?" categorized by class.

	Follow-up question: What did you think of working with value creation?		Ma2b	Ma1b	Ma1a	Teknik 1	Kemi 1
Categories	Good/Fun*		9	13	2	5	6
	Motivating with a recipient/goal				1	5	
	Motivating with purpose other than grades					2	
	Neutral / No opinion			4	3	1	
	Interesting / Educational		4	2	2	1	
	Different / New		2	5			
	Unclear / Did not understand		8	1			
	Reflective		1				
	Difficult		2		4		
	Bad		1		3		
	Total Reports (80)		**27/25**	**25/24**	**15/13**	**14/12**	**6/6**

*The majority of answers being singular "good" or "fun" confirms the prediction that students would be unused to elaborating on what factors that contribute to their summarized opinion. Student answers to the support question "What do you mean when you write that something is good, bad, or give a similar short opinion?" gave some further insights: The 50 relevant answers out of 80 total, at about 9 each include: no opinion, fun or enjoyable, not too easy or difficult, clear instructions, educational, and new or different.

Mission learning intents, reports and observations

This section contains a brief description of each mission, its learning intent, along with representative answers and observations. If not specifically mentioned, the duration of the lessons was about one hour. With a short introduction for each class and time lost to students registering for the app used to record data, the time students spent on their missions averages between one and one-and-a-half lesson.

Ma1a – Functions and exponentials

These missions were performed by a Vocational programmes class in their first year of high-school. The students spend half their week at school, the other half at their internship. Their school being further from Chalmers, support and presentations were held online. With students being at their internships frequently, there was extra opportunity to find VCP recipients. The three missions with the highest response rate are presented below along with representative answers.

By the teacher's request and to motivate students, the missions were tailored towards the different vocational programs. As mentioned in Method, the value created in math often comes from using tools on a set of values. The focus of the missions was translating spoken and thought mathematics to explicit written mathematical functions and terms, with the intent of revealing how often one uses functions in everyday life. Students were then to interpret and discuss their functions together with a recipient, usually their VET supervisor.

Student quotes from the mission Functions: How many?, for students with VET at pre-schools:

> *"It was a bit difficult because I've been working with children aged 1-3 years and they can't yet really calculate or understand when you're talking maths, but I managed anyway.*
> *"I learned a lot about how much and often a child actually uses math without you noticing it."*

Student quotes from the mission Functions: Linear logistics, for students with VET at stores:

> *"It was difficult to pinpoint the 3 most important functions, but I'd guess that graphs representing revenue and customers are top, because they are central for the business."*
> *"I don't know. I'm not sure I understood the mission, so I'm not sure I even did it right. But it was fun and interesting to discuss graphs and important measures with my supervisor."*

Student quotes from the mission Functions: Limitless exponentials, for all students, at their school:

> *" [example with rabbit population] ... but when it becomes super many rabbits the food will run out and then the rabbits die and the exponential function stops growing"*
>
> *"I explained exponential as a function that increases or decreases by a percentage and not value and that it never can be zero and pass through the origin."*

The mail conversations with the teacher and the student reports both average on the students' experiences being a majority of "Difficult, so I'm not going to bother even trying.", "Difficult, I hate it, but I did it anyway. Are you happy now?" and a few "A challenge, but actually quite enjoyable when I tried.". Despite reminders, engaged teacher and several available weeks, the general attitude ended up being reject and eject. This was likely due to the combination of previous attitude towards math, time and opportunity available at the students VET, and introducing this online.

Kemi 1 – Stoichiometry: Designing lab instructions

This mission was performed by a first-year class in the Nature Science programme. The mission was about designing instructions for small laboratory tasks or stations on a suitable level for classmates, using early feedback and iterations to find that level. The students were familiar with basic stoichiometry, calculating mole, concentration and limiting reagent from previous lessons.

This peer-instruction based mission started with the questions of “Who cares about the students’ knowledge of stoichiometry?”. Being a rather procedure-focused and basic topic, not too many. Primarily students themselves and teachers. Moving on to the “How can students contribute and show learning?” gave a more substantial answer. With the learning intent being applied and useful stoichiometry, writing the lab instructions for an upcoming lab to be performed by classmates gives a broader assessment basis and opportunities for feedback.

The average report included the lab instructions, but no answers to the questions included in the mission instructions. An illustrative example: *”how many moles are 2 g water.”.*

The most complete report handed in a complete lab-instruction and answers. Their quote below:

> *“We tried to make clear instructions that were easy to follow and understand. The goal of the task is that students should learn. Simply following instructions is not enough, they also have to understand why they are doing it.”*

With the intended lab introduced somewhat ad hoc and a slow start, few students got further than a relevant question and did not bother, dare, or ask for feedback on their drafts. The few who got further generally had an idea of the goal and did not ask for feedback either. The expectation that students had read enough lab instructions to recreate the format was somewhat too high for the given time.

This highlights one of the difficulties most missions had. One general learning intent of VCP is to understand how to show learning by using current knowledge to draft and iterate something. While an iterative approach may require more time, handing out an already complete template to follow the learning process of iterating and formative feedback would be lost.

Ma1c - Quadratic functions and exponentials

This mission was performed by a first-year class in the Nature Science programme. These missions are only given in full in appendix, due to no data recorded. Similar to the missions for Ma1a, their focus was on connecting real world applications for quadratic or exponential functions to their formulas by interpreting their graphs and coefficients. Discussion and graphs were to be recorded and handed in.

The missions were too abstract for many students. While they understood the written instructions, they lacked the mathematical tools to apply, translate and create the graphs requested in the missions. For the second lesson and mission the math teacher had prepared examples covering the initial steps of finding real world exponential systems. While this helped and enabled students to mostly complete the task, the original purpose of creating (as in VCP) was somewhat diminished. This highlights another recurring threshold, where students were not able to or did not attempt creating the first draft.

Teknik 1 - Project: History of technology

This mission was performed by a first-year class in the Technology programme. Unlike the other missions in this study, this larger project was designed by their teacher alone. Coincidentally, it was a very VCP-like project that suited this study well. Students were to create a game based on to "Chronology"/ "När då då?"[2] for history of technology specifically. The topic on its own has the future players as recipients, and the skills learned from working in the project format has many. The presented recipient was the principal and school as an organisation who wanted to publish the game.

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[2] Each player builds a timeline of cards, with each card listing an historical event and the year in which it occurred. The player scores by placing the drawn cards in the correct position in their timeline. More about Chronology at: https://boardgamegeek.com/boardgame/834/chronology

While having the principal as recipient is one factor, the engaged teacher acting project leader setting expectations and providing opportunities for students to show learning is probably the major one. The future players of the game had not been invited to give input yet, but the teacher mentioned the opportunity. The overall student attitude to the project was positive stress, novice but solution-oriented, and high engagement. Recipient, teacher and motivated students, but how to show learning?

By dividing the work among groups with deliveries for, and dependencies on, each other, different groups were assigned different responsibilities and task. To generate comparable assessment basis for the course curriculum, all students also had the task of creating some playing cards each with content about history of technology, supported by reports for each card.

With an already defined and progressing project, only the reflective questions about VCP were asked. Several students mention the value creating part of the project as motivating:

> *" [The project] hasn't been anything special, I've just tried to do it the best I can like any other task. It is a bit fun to do it for a reason and not only for the sake of doing it."*

> *"I think it has been more fun than doing more theoretical tasks where you're only doing it for the grades. I therefore feel more engaged in the project."*
> *"It felt more enjoyable to develop something that is useful for something. It also makes the work itself more serious and rewarding when finished."*

The reflections on learning and feedback still show some unfamiliarity:

> *"I don't reflect too much about what I have to learn. It happens in the meantime and since it's not very demanding things to learn, like in other subjects, I don't think about it."*

> *"I actually don't know what my recipient thinks of my contribution. Maybe one can get feedback on the project later."*

Two quotes from the classroom that also illustrate the engagement: *"That was supposed to be done last week?!"* - One of the student groups to another student group, in good spirit but slightly annoyed. And "*Can't we vote for finding a better alternative?"* - Students during a vote for selecting the name of the game. Submissions had been open for two weeks before the election.

Ma1b – Statistics: Tables and analysis

This mission was performed by a first-year class in the Business Management and Economics Programme. In practice this was four classes for a total of about 100 students and 4 teachers split in two mixed groups with lessons scheduled in parallel. This meant some logistics to broadcast the introduction and then visiting the other classrooms during the lesson. The students had attended one lesson prior on the topic of statistics.

A lot of people care about statistics, but for different reasons. Stock markets, big data, marketing, retirement funds are just some examples. But why do they care? The first step is input, usually tables. While some trade this data raw, this is only digit in rows and columns. It is with the correct interpretation of these digits that valuable decisions can be supported and made. Letting students create and record the data to analyse and give value to, by asking them to describe their method and how it supports their findings, the mission should be an opportunity to show learning.

The first mission focuses on separating the terms randomness, correlation, causality and how to perform a simple study using dice to generate and analyse random data. Most students found trends and raised objections to their reliability but could not clearly define or motivate why. Two quotes showing the common confusions:

“That the minute digit probably doesn’t affect the dice, which you might otherwise believe. Weekday however might affect though.”

“I understood [what to do] after reading the instructions, but I did not understand why we were rolling dice.”

The second mission connects to the previous mission about dice, with a more defined emphasis on analysing and interpreting the data generated, this time using rock-paper-scissors. A different mission, but also an iteration. With students recognising the format, there were more mentions of not only recording the data, but also using the data to achieve something, examples from the quotes below:

“You think more when one documents and reads ones’ ‘behaviour’.”

“The instructions were difficult but I learned that I won the most times using paper, but that it most often is random.”

“I learned to take notes for a study and analysing the results. It was fun to do something new and different.”

The students did create tables, artifacts, and made valuable comments, but motivations and discussions rarely reached paper. The question of "This is fun, but why are we doing this?" was frequently asked. Friendly curiosity, but with the expectation on the teacher to provide an immediate answer. The instructions were simple enough, and with a little more time in a following lesson helping the students reflect another round on the purpose of the mission would likely be beneficial.

Ma2b – Statistics: Methods for mean and median

This mission was performed by a second-year class in the Business Management and Economics Programme. Like Ma1b, this was four classes for a total of about 100 students and 4 teachers with lessons scheduled in parallel. The focus on this mission is interpreting, extracting, and visualising relevant statistical measurements from graphs based on real world data using boxplots, mean and median. To help the students stuck after the first lesson, templates for the expected results was also provided, see Appendix Missions.

With a similar motivation here as for statistics in Ma1b, the mission requests students to find and interpret data, motivating their findings with graphs and short descriptions.

The major hurdles turned out to be basic computer tasks: Few students had ever taken screenshots, used the snipping tool, paint or actually worked in parallel on an online document. Other observations were that insightful student discussions rarely reached paper and that boxplots were an unfamiliar tool. A single group out of all the students completed the entirety of the mission, showing that the level is not unreasonable. One important difference in approach noted when talking with that group was: “We think this is what you requested, and here’s why.”.

Student quotes and reports from the mission vary:

” [I learned to] use paint and read a diagram”

“Many different technical steps, but fun. Thumbs up!”

” [discussing graph about GDP/capita] … the few who earned very much earned way above the average, balancing the many who earned much less”

“Interesting format with real world data, but difficult to understand what to do, like plotting min, max and median values.”

The intended value from discussing, comparing, and iterating methods and motivations between students was generally not achieved. The second step in the instructions was outsourcing part of the work to a classmate as recipient. With most students stuck on the first step of how to create their first draft, this mission result mostly only reached the level of task and solution.

Notes and quotes

Data not logged by students, but observed during visits at schools, meetings with teachers or students or in mail conversations.

Teachers as researchers

With the project leader using a method for research in education, one question asked to teachers was how they could and would prefer to perform their own research in their school environment. There was general agreement on some discrepancy existing between academia, practice, and politics. With an often top-down perspective or implementation, the effort to study what works and is relevant for practice on the same level was carefully but positively received. Support from the school management to coordinate multiple teachers in a research project was not mentioned. The general response was that they, with varying frequency, did record and evaluate individual lessons, commonly by using exit-tickets, student quizzes, taking notes or discussing with other teachers.

The initial and one-off steps to scientifically gather data to analyse by teachers happen, but the often missing step was time for repeats and efficient tools to log, compare and share their results.

Feedback from participating teachers

The participating teachers already had interest in what VCP could bring. Motivations for participating included updated syllabus where VCP could bridge the added emphasis on profession, finding answers to the student question of why, motivating students, and goodwill for a thesis, often in combination. Fears mentioned was regarding student attitudes and not participating, technical dependencies, and how to use the student reports as assessment material.

A common question before the missions was “How can we help the students with the missions and during the lessons?”. To review and simplify the mission instructions before going live, provide and present goals and templates, and gently provoke reflection. The classic counter-question “What do you think?” has merit. Teachers also forwarded appreciation from the students.

5 – Discussion

This chapter will focus on the lessons learned from this first attempt at VCP in STEM, discuss the challenges and opportunities encountered in the study, compare results and good practices, and draw some implications for future studies and use.

Challenges encountered

The primary challenges for this study were finding teachers willing to participate and share their time. Finding teachers that trust a guest to successfully manage and lead a classroom, and teachers already working overtime to remediate the post-pandemic situation, were both circumstances that were hard to influence. With these challenges in mind, the minimum number of participating teachers required was set to only five (5), and a minimum of students at about a hundred (100). With less data, especially at the predicted level of detail in students' reflections, it would likely be hard to conclude anything significant.

Systemic challenges for VCP

From the student answers regarding *where*, rather than the asked *how* to show learning, there are hints of students learning *the system*. The quote from the question of why to learn; "*I ask in a mostly ironic way if we receive a difficult, repetitive, or boring task. I know it likely is good to learn whatever it is and that I don't really have a choice."* is again relevant. Students do want to understand, but also seem to lack the tools or habit to reflect over what they understood. This contrasts with how VCP encourages students to be aware of and elaborate on their own learning for an action or experience.

Related to the *why* is also the *how*. Students reporting the instructions being unclear often had trouble visualising the final artifact, be it lab instructions, tables, or figure captions. Ordinary tasks usually ask for imperative results, skipping or only implying the plan to get there. This contrasts with how VCP encourages an iterative approach.

For the teachers, the question of *how* also gets the addition of *when*. Current teachers as researchers sample individual lessons. Without the tools, support, and time to analyse and give feedback to student responses, teachers will have a hard time scaling up their efforts for improving educations in a scientifically supported manner.

Defining value is another challenge, especially since it is often interpreted as being limited to economic value. While student-run start-ups might make a useful learning platform, projects for profits sake competing with time in school has been thrown some shade.

Errors stemming from shortage of time

With different missions between many classes, time of day, students previous experience and level, incomplete answers, low frequency of response for some missions, project leader iterating the material between classes, time lost to students registering, online or on location and translations, there are many small factors which makes it difficult to directly compare the report data. While somewhat mitigated by the discussions with teachers and observations, the lack of time remains the primary shortcoming.

Opportunities

While the results vary in quality and quantity, there are highlights worth discussing. A foundation for any education is students that do want to learn. With or without reflective tools, the overall positive response that sometimes also highlight the recipient, even after only these initial attempts, shows there is indeed opportunity for VCP to bring motivation for learning. The positive attitude in the student quote below is one clear example of what VCP strives to achieve.

> *"It felt more enjoyable to develop something that is useful for something. It also makes the work itself more serious and rewarding when finished."*

Filtering the reports by those who understood and completed the missions, there are more hints of the motivation and reflection the missions are intended to create. Another positive student quote:

> *" [The project] hasn't been anything special, I've just tried to do it the best I can like any other task. It is a bit fun to do it for a reason and not only for the sake of doing it."*

While this study is unable to measure the desired improvement in learning, both these quotes and others also hint at more competencies than an ordinary lesson or task.

Encouraging students to be aware of and elaborate on their own learning

How to show learning? Terms such as competencies, skills, attitudes, knowledge are common units to measure learning relating to an action. These actions can very well be the tests, lessons, or discussions students mention, making part of the foundation for reflection already in place. However, judging from the only two of 200 students answering with reflection, there is likely something missing.

Spending time on working with the question, giving feedback, and helping students elaborate is likely one part. Again the two out of 200 reports mentioning describing and repeating procedure are from Ma1b, reporting on their second missions. If the reflections can improve by just a single mission iteration, there is great potential for when more time is given.

Missions with a defined learning intent and recipient as an action to reflect about is another. Attaching a recipient answers the question of "Who cares about my knowledge?", hinting at "What knowledge?" and "Why do they care?". This can hopefully bridge an answer to the: "What exactly is it that you do during tests etc. that shows what you have learned?"

Students reflecting on their learning also benefits the teacher (Yaacob, 2021). Students often have a good sense of how well a mission or task was made. Feedback becomes easier, sometimes superfluous, when both sides come prepared. Disparities between reported and factual can be identified and resolved.
The assessment responsibilities remain the teacher's, but the work can be both simpler and faster if the student can clearly communicate the assessment basis.

Encouraging an iterative approach

Formative feedback improves learning (Wisniewski, Zierer, & Hattie, 2020), but receiving feedback is sometimes scary and giving it sometimes difficult. A behaviour some students repeated was "I'm bad because I've not done anything yet.". Overcoming that threshold and reaching "This is bad." shifts the focus from the student to the artifact, enabling constructive instead of personal criticism. An opportunity for students to escape a self-victimising approach to avoid learning.

Giving feedback also takes time, especially if there is a lot of material to cover. By setting and motivating directions from early drafts and outlines instead of reworking later, both students and teachers can save time. The recipient is also likely a busy person and can for the same reason be involved early. One student illustrates a common uncertainty:

"I actually don't know what my recipient thinks of my contribution. Maybe one can get feedback on the project later."

This mirrors the easy mistake of giving instructions, then asking the wrong question: "Did you understand?". A much more constructive question would be asking the student to repeat why each step is necessary or relevant. In the VCP scenario: The recipient requests a contribution, the students create a template draft, and then the draft is iterated. "We think this is what you requested, and here's why." The few students who did fully complete the missions given were the ones that had a similar approach.

If asking the recipient early what value they are looking for, then using appropriate tools for creating it, there are opportunities for showing more skills and abilities outside procedure to the finished contribution alone.

Enabling teachers as researchers in a time-scarce school

With the initial steps to research already surfacing by own initiatives, it is not a lack of motivation to improve that hinders the progress. To manage a greater data set for evaluation and assessment, teachers need the tools, support, and time to analyse and give feedback to student responses. The support usually means leveraging resources from higher in the organisation. The tools exist but need introduction and someone to coordinate projects with many teachers involved. Additional time rarely exist, unless something already taking time can be done quicker. Efficient tools are one way, but the major enabler with VCP is the opportunity to help students provide better assessment basis as data. Self-reflection and assessment, comparable and predefined tags, and catching time-sinks early by working iteratively ultimately saves time for the teacher.

Student attitudes, reflections, and expectations

Do student attitudes embrace new experiences as exciting, or do they eject and reject? With varying skill levels and attitudes, the emotions reported probably better reflect the general stance to novel pedagogy or change rather than the content of the missions. In hindsight, having two missions prepared, each probably accounting for two lessons and cramming both in the given time was unrealistic. Most classes only barely managed one, and the second one was thus not presented at all. With the strongest correlations to emotion being difficulty or clear goal, a briefer and simpler first mission with an explicit template goal to reach would likely have yielded higher emotion scores. With results of an overall slightly positive emotion and plenty of reports stating "good" nevertheless, new attempts should be welcome.

Learning a new tool is mostly a question of establishing a new habit, but also intentional practice. The one surprise was that students who had been working with school tablets or computers since mid-elementary had never used some of the basic software tools available. While young people are often credited for their technical ability, leisure browsing is hardly a skill compared to using a computer as the powerful office tool it can be. Instead of taking an active approach using online search engines to find tutorials, tools, or entries to the missions, students often waited for the teachers acting search engines, waited passively or gave up. With digital literacy often being an expectation, and sometimes a requirement, for inclusion in a digital society or workplace, missions encouraging students to learn and apply these skills can also serve as real life preparation.

Implications

The students learn for themselves. External recipients can help motivate. The final key player is the teacher. To keep the study from being an estimate of how good the project leader was, this important part has been downplayed until here. Do not underestimate the teacher's role as the primary or secondary recipient for all missions.

A clarification to be made – a recipient does not plead for contributions. They request and motivate why it is valuable for them. While "Because it would make me happy." is motivation enough for some missions, a more defined expectation also helps the student. "I want you to contribute to this artifact so that I can give relevant feedback and help you learn." This also puts the responsibility on the student, instead of binding the student motivation to their relationship with the teacher.

To help students who had trouble getting started or visualizing the goal, placeholder templates picturing the overall document structure was prepared for the Ma1b and Ma2b missions. These intentionally had factual errors to discourage copy-pasting and to test the students' knowledge of the topic. Identifying what content to keep and what was false provided opportunity for discussion within the groups. If the students require templates, the learning from creating and seeking feedback part of the VCP format will be skipped. While the templates provided did enable more students to complete the mission, practice for a gradually decreasing dependency on templates will be needed before students can fully utilize learning from creative iteration and seeking early feedback.

Skills in matrices are a common measure of what has been shown but does not always clearly explain how. The tags used in VC research are one attempt at helping students phrasing their learning in comparable terms. Tags were only being briefly introduced in this study. With more time, tags could be one way to discuss expected learning outcomes with students.

To enable an effect study of how VCP missions impact motivation and learning, the support from the organization's leaders will be needed. Someone needs introduce the tools and coordinate multiple teachers and classes over longer periods of time to be able to find the general trends.

With time often being the limiting factor for teachers, not having to reinvent the wheel or repeating the process of trial and error is beneficial. To help teachers to both motivate and start working with VCP, a library of missions to adapt, present and evaluate is available in Appendix M.

Ideal numbers for this one-person project spanning a full-time semester, were approximated at ten teachers, about 250 students, with each participant providing three completed reports. This in turn would have required about 20 to 30 VCP missions prepared, as classes differ in program, year, subject, topic, and average skill. With hopefully less post-pandemic overtime for teachers in the future, a repeat study of similar scope would likely have the opportunity for more time per class.

6 – Designing VCP missions for STEM

This chapter aims to answer the original question of: How to design Value Creating missions that increase student learning and motivation for STEM subjects at high-school level? by providing a step-by-step method with considerations based on the results and lessons learned from this study. While this is the method iterated upon during the study, this final version is given its own chapter as it is one of the main contributions by this report and for ease of access. The finalized and general flowchart for the design process is shown in Figure 2 below.

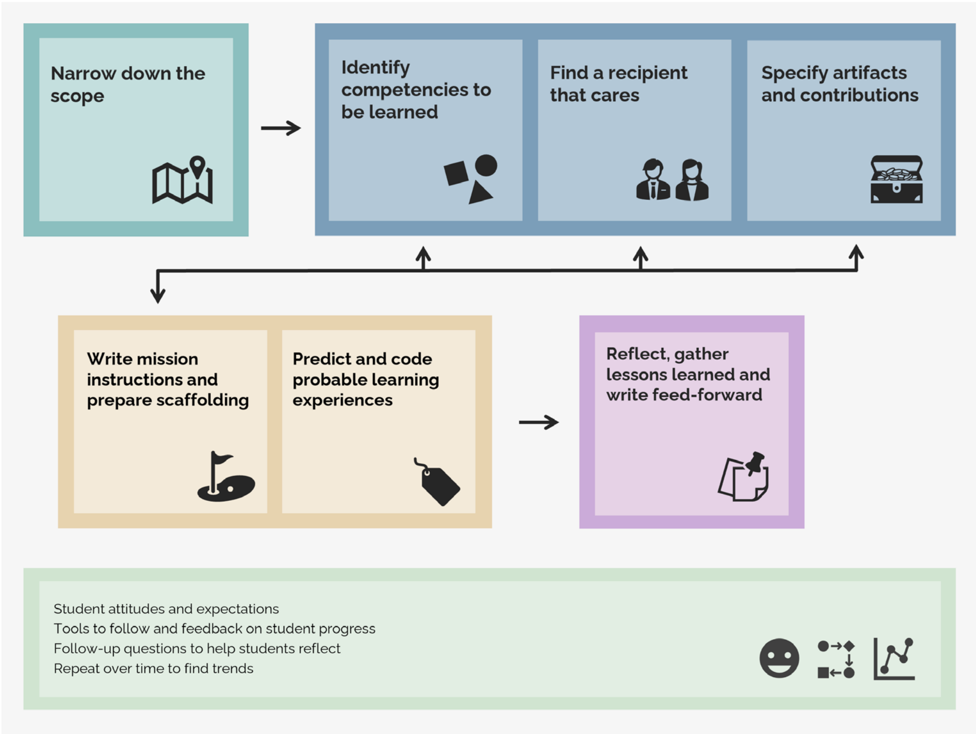

Figure 2 – A flowchart showing the design process creating for a value creating mission.

To design Value Creating missions for STEM subjects at high-school level, the process starts relatively linear, then revisits earlier steps when iterating mission details and instructions. Each step has one question that can be used to guide the designer and check for completion.

Step 1: Narrow down the scope

The first step is to know your subject and narrow the scope down to a topic. Titles should be found in the course curriculum or similar documents. The topic itself is also usually assigned a timeframe of some weeks or lessons in the calendar.

"What and when are we learning?"

Step 2: Identify competencies to be learned

The second step is to identify the competencies related to the topic. There are usually plenty of tasks or problems to borrow and or be inspired from for all STEM subjects. Extracting the resulting artifacts from these tasks, often an ideal worked example, allows the learning intents to be modularized and easily identified. With the artifacts listed, find their dependencies. This helps position how much time and introduction the students might need to learn the tools required for the mission.

"What tools do we have and need to show learning?"

The first and second step are both found in the course curriculum and syllabus. The answers to “What do you think you have learned by doing this mission?” are a measure of how well this was transferred.

Step 3: Find a recipient that cares

The third step is finding a recipient. The question of ‘who cares’ is preferred over ‘who uses’, since there might be value in the recipient learning, regardless of actual usage. Inviting the students in this step to both contact and reflect over possible recipients is added opportunity for learning (Lackéus, 2022, pp. 158-159). With the widest scope of outside school, there are likely professions that cares for the chosen STEM topic. If the academic level is different, the value created can focus on being more social, educational, or environmental. Similarly for in-school missions, another class or teacher likely has different interests outside of STEM. In class, the level is somewhat similar but the new experience from an outside recipient is missing. The value here can focus more on the topic, especially on methods and motivations. Save the contacting and pitching the mission until you have a draft and expect some effort to find a willing recipient. Depending on class experience and confidence working with VCP, adapt student responsibilities to their current level.
“Who cares about students learning this?”

The student answers to the questions of “What did you think of working with value creation?” and “What makes you ask why you need to learn something in school?”, especially from Teknik 1, supports the motivation from a recipient.

Step 4: Define how students can show learning and contribute value

The fourth step is answering how students can learn and contribute. The artifacts could be descriptions, methods, motivations, replicated procedure, discussions, illustrations, etc. For STEM, the value often comes from not only replicating or generating data, but in analyzing, interpreting, and discussing it. Described with report titles, this would be an emphasis on discussion and method. The results are still the basis, but only recreating tables or figures would be missing the opportunity to also show the learning from motivating what lead to the results and its implications. What exact artifacts students should contribute depends on the topic and learning intent matched with the interest of the recipient.
“How should the students use the tools from step 2 to show that they have learned this and contribute value to the recipient?

The student answers to the question of “How can you show the teacher what you have learned?” and their dependency on scaffolding highlights the need to define the artifacts and contributions in advance.

Step 5: Write mission instructions and prepare scaffolding

The fifth and most iterative step is writing the instructions and preparing any relevant scaffolding. Like in step 3, inviting students provides opportunity for added learning. Their thoughts on how they would write instructions to achieve learning and with what tools is both preparation and reflection. Colleagues and recipients can also provide valuable input.

Here revisiting in order; contributed value, recipient, competencies and landing in tasks that will be part of the mission. With identified and selected artifacts, translate instructions that if read and understood correctly results in the student replicating the artifact with their own motivations and content. The

instructions should also define and introduce the recipient, suggest early contact with the recipient, seek feedback on an early draft, specify in what order and when to perform the mission steps, and in what format to report.
"What exactly should students do to learn?"

With competencies being the learning intent, the instructions should specify what to achieve and suitable tools to do so, but preferably leave the how for the students to learn. An introduction or request from the recipient serves the same purpose. If students have trouble visualizing the goal, placeholder templates outlining parts of, or the final result can help. Adapt how explicit the initial specification is based on student experience and available time. If too obvious, the step of seeking feedback on an early draft is lost, making a value replicating rather than a value creating mission. While the teacher is always available to help students learn the how, if the recipient has time and interest, continuous guidance like a master to an apprentice is also welcome.
"What are the students' goals and who or what provides enough guidance to get there?"

The frequent student answers of instructions being unclear shows the importance of iterating and providing scaffolding until self-dependent. The support from teachers as recipients in the classroom was also valuable.

Step 6: Predict and code probable learning experiences
Having instructions and preparations in place, the sixth step is to help the teacher to get an overview of the students' learning experiences and to help the students report their learning experience. It might be hard to fit all desired competencies in one mission or compare several student reports. By trying to predict what learning students may encounter and including them as premade checkboxes or tags that students self-report the teacher can get an overview of both what the mission achieved and if there are disparities between students reported learning and their artifacts. This is also a good time to add any topic-specific questions to the mission.
"What learning do I think students will encounter and notice?"

Answers from Teknik 1 show that predictive tags also help students elaborate. Reports tagged with "The goal of the mission was clear" also mentioned why in their texts. While there was little time to assess the reports together with the participating teachers, the examples looked at sparked discussion on how collaborative assessment could be simplified using tags and used as a method for gathering research data.

Step 7: Reflect, gather lessons learned and write feed-forward
The seventh and final step is assigning some dedicated time to reflect on the lessons learned and transfer feedback to feed-forward. From learning and identifying to adjusting behavior and action. This is relevant for students as preparation for upcoming missions, for recipients in similar collaborations and teachers for designing additional or repeating missions.
"What are the lessons identified, and how can we make those to lessons learned?"

With the more reflective answers and complete artifacts coming from the students who repeated similar missions or had started their project earlier, there is clear indication that feed-forward and reflective questions help students to learn.

Supporting steps and considerations

The steps above focus on the design of the missions themselves. There are also surrounding conditions and expectations that can be managed to aid the missions. Main considerations encountered so far are time, student attitudes, tools, follow-up questions, reflections and contact with recipients.

Starting with time, most of the missions in this study and in Appendix M are from experience suitable for about 2-3 hours each. In a classroom setting, this would likely be one lesson of introduction, first draft and early feedback, and a second working with the feedback, finishing and reflection. Reaching and working with a recipient outside the classroom likely takes more.

The majority of the answers to the question of “What did you think of working with value creation?” shows that student attitudes are generally positive. Setting the expectations for an iterative approach includes learning from failure. By emphasizing the learning, and noting that failure is better than not trying, especially if giving feedback that brings more learning and less future failure, most students will remain positive. To those students that are initially less positive, a constructive expectation to set is “I want you to contribute to this artifact so that I can give relevant feedback and help you learn.” This puts the responsibility on the student, instead of binding the student motivation to their relationship with the teacher.

The term tools here refer to the office tools a teacher can use to manage the student progress and reports. While software likely is more efficient than paperwork, a system for receiving student reports in a comparable format and that can be given feedback in a timely manner will be needed.

Follow-up and reflections overlap. Students often have rich motivations but are less often given opportunity or push to elaborate. Asking for further why, how and specifics will likely be unfamiliar at first, but also appreciated, and when habituated provide the teacher with more nuanced assessment basis. This process of inquiry and feedback is another reason for efficient tools for written communication and documentation.

Contact with recipients outside school was not tested in this study, but some general tips based what the contacted teachers often requested is presented here. Having a mission draft specifying when, what, and the requested feedback format is a start. Adapt the mission to the recipient if it doesn’t diminish the learning. Expect most potential recipients to be busy. Students can find and contact recipients too, preparing for that contact is also an opportunity for learning.

While the considerations are not exhaustive, the reader following the steps above should have enough to design Value Creating missions for STEM subjects. The overall workflow is likely applicable to areas subjects outside of STEM, but the recipient and typical value created in other areas are yet to be explored.

7 - Conclusion

First, a word from this study's participants:

"Good" – Many students when answering the question of "What's your opinion on working in VCP format?"

While limited in scope and time, the simple but positive reviews from the main recipients of this study is indication enough that this is worth further time and studies.

With the intention of testing and developing a method for how to design Value Creating missions that increase student learning and motivation for STEM subjects at high-school level, this study achieved most of what it set out to. To measure the learning was out of reach given the limitations, but there are clear indications of motivation. The method for how to design Value Creating missions is in the report and the missions tested are found in Appendix M.

The supporting questions helped highlight reflections as a powerful but underused tool for learning and iterations as an efficient but also underused tool for learning. Observations from the classroom illustrated how value creating missions can be opportunities to gain life skills and try real life applications. Using tags as comparable assessment basis saved time when giving feedback and discussing expected learning outcomes with students.

Despite this only giving a preview of the intended value creation, the next relay can hopefully use the results so far and really evaluate what value and creation brings to the students' learning and motivation. They will still likely have to contact a couple hundred teachers, reuse or design several value creating missions, iterate those in collaboration with the participating teachers, introduce their choice of data recording tools, present and explain value creation, discuss expectations and observations with teachers, and analyse the sometimes insightful, sometimes janky student answers.

With some more time and practice on well-designed value creating missions, maybe the students' answers will be something along the lines of what I'd answer to "What's your opinion on working in VCP format for your master thesis?":

"Good, because I learned something new, the recipient was nice and gave helpful feedback, and I'm proud of what I created."

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Appendix M

All missions created for this study. The missions tested in classrooms have a blue header, the others that were created but not tested have a purple header instead.

Reflections – Value Creating Pedagogy

Background:
Hello Student! Thank you for participating in these value creating missions. I hope it has been rewarding! When Students are asked to evaluate they often reply with "Good." The person asking probably agrees: "Good for you that it was good, but what exactly makes you summarize it as good?

Mission:
...

Write your reflections here in LoopMe:
- What do you mean when you write that something is good, bad, or a similar short opinion?
- What makes you ask why you need to learn something in school?
- How can you show the teacher what you have learned?

Attachments:
...

Follow-up question: What did you think of working with value creation?

Ma1a – Functions: How many?

Background:
Young children also use math, Preschool teachers want to let children learn math by playing.

Mission:
Part I: Find at least 2 simple mathematical questions that the children can answer.
An example could be "How many will there be left if we remove one?"

Part II: Use your own math skills to translate the functions the children are using when answering your questions. Example: To remove one can be written as "f(x) = x-1".

Part III: Discuss with the preschool teachers what math they have seen the children use. Refer to your questions and functions from Part I & II. Write down a few sentences with highlights from the conversation.

Write your reflections here in LoopMe:
- How and what did the children do to answer your questions?
- What mathematical questions do you answer an ordinary day?

Attachments:
A document with your questions, functions, and notes from the conversation.

Follow-up question: What do you think you have learned from this mission?

Ma1a – Functions: Linear logistics

Background:
Warehouses and logistics are full of linear equations and functions. "If you stopped buying groceries today, when would your fridge be empty?"

Mission:
Find someone at your internship who manages inventory, logistics or economy. Together, find at least 3 functions relating to their work. Illustrate the functions in graphs. Add a brief description in text designed to help a new employee to understand and prioritize their work to each graph. Helpful questions to answer could be: What is the first thing to run out of stock? Which functions should be constant? How well does the function predict the future?

Write your reflections here in LoopMe:
- Which are the three most important functions for you at your internship?
- Are all linear relationships time-dependent? Motivate briefly.
- How often do you need to explicitly print functions in everyday life?

Attachments:
A document with graphs, descriptions, and answers to the questions in Mission.

Follow-up question: What do you think you have learned from this mission?

Ma1a – Functions: Limitless exponentials

Background:
Exponential functions can like other functions be used to predict when a system reaches a certain value. Environmental and Sustainability systems are often exponential. There is often a physical limit for what values can realistically achieve. How to predict when an exponential model becomes unrealistic?

Mission:
Discuss exponential functions with at least 2 persons, preferably outside the classroom. Be prepared that you might have to explain what the term exponential means. Find suggestions of how to identify and avoid threshold values for when the system you are discussing collapses or creates other consequences. Take notes and briefly summarize what system, suggestions and explanations that you used.

Write your reflections here in LoopMe:
- Why is not all systems linear?
- What exponentially decreasing systems affect you in your everyday life?

Attachments:
A document with brief summaries of the discussions, systems, suggestions and explanation of the term exponential.

Follow-up question: What do you think you have learned from this mission?

Chemistry 1 – Stochiometry: Designing Laborations

Background:
Chemistry teachers sometimes reuse labs from other people with chemistry knowledge. Students learning chemistry also have some knowledge. Students often want to know what level or grade a task is meant to test.

Mission:
Create a part or station of a lab for practicing stoichiometry. Your station should involve mole, conversions between mass, concentration, or balancing reactions on a level suitable for your classmates. Seek early feedback about your written instructions from your classmates or teacher. Keep in mind that your instructions will be used as is during the lab; try to help your classmates learn,

Also create a clear proposed solution to your part and use it to motivate what skills and level it aims to test.

Write your reflections here in LoopMe:
- What did you include in your part and instructions to help your classmates learn?
- What makes a chemistry task challenging, but not too easy or difficult?
- For whom (beyond professional chemists) is stoichiometry important and or useful?

Attachments:
A document with your lab instructions, proposed solution and motivation for what level.

Follow-up question: What do you think you have learned from this mission?

Reflections – Value Creating Pedagogy - extended

Background:
Hello Student! I hope you also find the card-game project about the history of technology exciting! In my thesis I studying what students think about having a recipient for what you are learning. You are of course learning for your own sake too, but also for everyone who is eventually going to play and enjoy the game.

A short tip for the questions: When Students are asked to evaluate they often reply with "Good." The person asking probably agrees: "Good for you that it was good, but what exactly makes you summarize it as good?

Mission:
...

Write your reflections here in LoopMe:
- How much thought do you give to what you need to learn to make the players enjoy the game?
- How can you find out what the recipient thinks about your contribution?
- What do you think you have learned from this project?
- What makes you ask why you need to learn something in school?
- How can you show the teacher what you have learned?
- What do you mean when you write that something is good, bad, or a similar short opinion?

Attachments:
...

Follow-up question: What did you think of working with value creation?

Ma1b – Statistics: A reliable study

Background:
If an apple always falls towards the earths center of mass, gravity seems to be the cause of the apple falling, implying causality. Spurious correlations such as movies released starring Nicolas Cage and drowning incidents per year correlates does perhaps not imply causality.

Mission:
Create a part a study that shows how the last digit of a digital clock (0-9) correlates to a certain dice result (1-6). Example: "If the time digits end on 2, the dice results are more likely to show 5." Using your logged results, try to convince a student that has different results or has not done the same study that your results imply causality. Write down the arguments used for and against. Finally describe the instructions of this mission to your partner and help each other specify what makes your study reliable or not. Try using relevant terms (random, expected value, average, etc.) when discussing and in your notes.

Write your reflections here in LoopMe:
- What common correlations are you using in your everyday life?
- Where do you find the data or statistics that support your actions?
- In what/which common situations are statistics used to support arguments?
- How can you repeat the study to provide a more reliable result?

Attachments:
A document with your time and dice results, arguments for and against causality, and an explanation of what makes your study reliable or not.

Follow-up question: What do you think you have learned from this mission?

Ma1b – Statistics: Hands and happenings

Background:
Rock-paper-scissors is a classic game that is often considered fair and random.

Mission:
Play rock-paper-scissors and track what hands are played in tables for a total of 10 wins. Repeat with another person. Look for two trends in how you played. Example: "I always played paper next if the opponent had shown rock twice before." Write down these two trends. Before repeating with two new opponents, share your trends. After the second round, find, write, and share trends before the single final round.

Together with your final player – Analyse and compare your results to try to separate why the question "Is rock-paper-scissors a game of dependent or independent events?" is tricky.

Write your reflections here in LoopMe:
- Are there always trends in data? Motivate briefly.
- Can a system be both dependent and independent at the same time? Motivate briefly.
- When is risk a complementary event?
- How can you repeat the study to provide a more reliable result?

Attachments:
A document with your own tables of rock-paper-scissors results, written trends, and an explanation of what type of events rock-paper-scissors are based on.

Follow-up question: What do you think you have learned from this mission?

Ma2b – Statistics: Methods for median and average

Background:
Statistics are a powerful tool for measuring and describing how the world develops. The data for this mission is found at: https://www.gapminder.org/tools/#$chart-type=linechart.

Mission:
Part I: Familiarize yourself with the interface. Click the top left menu to change units and filter by the list of countries to the right. Find a graph that you find interesting. Preferably choose one with units that you can interpret, such as age, population, or income. Use the snipping tool, screenshots or copy by hand to paper to save 2 images each of the chosen graphs Use any picture editing program such as paint, or physical pen and paper to mark the statistics for the mission.

Part II: Open your first image in paint. The trend lines shown are often averages. For three different points on the x-axis, draw a boxplot of how you think the underlying data looks at that point. Save your first image.
Open the other copy of your first image. Find and mark an interval where the average and median are close. Find and mark a second interval where the average and median differ as much as possible. Save the copy.

Part III: Outsource Part II for a second graph to a classmate. "I would like you to interpret this graph for me." You will receive theirs and also repeat Part II. Compare and discuss the work you did for each other.

Part IV: Cooperate with your partner and Repeat Part II for a third and final image pair each. Insert all 6 images in a document. Add a brief description for something relevant in each figure. Examples: "The boxplot max was drawn here because…" "The median and average are close for this interval because …".

Write your reflections here in LoopMe:
- What preconceptions about the countries influenced how you placed the boxplot?
- When can one not calculate the median or average?
- Which term is the most difficult to define, median or average? Motivate briefly.
- How much explanation is needed to make someone else understand what you have done?
- How did you and your partner's methods differ?

Attachments:
A document with the six figures and their descriptions.

Follow-up question: What do you think you have learned from this mission?

Ma1abc – Algebra: Adults and order or operations

Background:
Tasks dependent on order of operations sometimes show up in social media. While often intentionally vague, there will be entirely incorrect answers in the comments regardless.

Mission:
Create a task dependent on order of operations. Write your own clear and instructive procedure for solving the task. Then ask a recipient to solve your task and present their solution as clearly as they can. Save their solutions and compare it to your own solution. Discuss differences and similarities in how you solved the task with the person. Repeat with at least three different persons.

Finally – apply your gained knowledge by helping a classmate to solve your task as well as possible.

Write your reflections here in LoopMe:
- What constitutes a really good solution?
- How much detail is necessary for a solution?
- Which of these good practices do you apply when solving mathematical tasks?
- How do you remember the order of operations?

Attachments:
A document with your task, your own solution, the recipients' solutions, and the solution you helped your classmate create.

Follow-up question: What do you think you have learned from this mission?

Ma1a – Terms: Cost analysis and blueprints

Background:
In what situations are cost analysis and blueprints used?

Mission:
Use available connections to find a (part of a) finished, current or future project that used a cost analysis and a blueprint. Write a summary of the mathematical terms that are required to describe the project plan and execution. Use your list of terms to clarify or explain a part you think is unclear. Compare your terms and explanations with a classmate. Work together to motivate why your explanations and terms could help your projects succeed. Write down at least two arguments that you find.

Write your reflections here in LoopMe:
- What methods regarding blueprints, material and economy would you use to motivate your price for a project?
- How often do you as a customer have insight on why a project is priced as it is?
- How would you implement the project? Give a brief overview.

Attachments:
A document with the part of the project you have worked with, the list of mathematical terms and the arguments you found.

Follow-up question: What do you think you have learned from this mission?

Ma1b/Ma2b – Economy: Interesting House

Background:
Moving out and finding your own residence is a common step after graduation.

Mission:
Find an advertisement for a residence that you would like to purchase. Investigate how much it would cost for you today to take a loan and move in. What would the yearly interest and amortization be? Calculate using suitable software or tools. In the next step you're considering renting out your residence. Discuss with a classmate and motivate how much the monthly rent should be. Use and write down relevant mathematical terms that you use. Finally find some model or analogy that explains why interest exists and present it here.

Write your reflections here in LoopMe:
- Where does interest come from?
- Would you with an average salary for a common job after your education afford to live in the residence you've investigated in this mission?
- What is your plan for repaying the loan taken?

Attachments:
A document with a screenshot of the advertisement (containing price and size), method for how you calculated the interest and amortization, the motivation and terms used for monthly rent and the model explaining interest.

Follow-up question: What do you think you have learned from this mission?

Ma1abc – Functions: Graphs and giraffes

Background:
Giraffes are fun animals. Graphs sounds similar to giraffes. Younger students often like animals.

Mission:
Create a part of a lesson for a small group of younger students exploring how to interpret graphs using giraffes to visualize functions. Prepare three different graphs showing how a physical property of a giraffe affects how tall it will be. Examples of giraffe properties could be neck length, weight or number of legs. The younger students' task is to draw how these giraffes would look like if they are to reach a very tall tree (20m), an ordinary tree (4m) and to drink water (0m). Help the younger students interpret the graphs. Write down at least two reasonings that lead to a strange giraffe.

Write your reflections here in LoopMe:
- What pros and cons are there regarding the models you created?
- Which of your explanations helped your students to understand the most?
- When is risk a complementary event?

Attachments:
A document with a short lesson plan describing how you intend to explain your graphs, a picture and description of your students' favourite giraffe.

Follow-up question: What do you think you have learned from this mission?

Ma1abc – Trigonometry: A rule of thumb

Background:
Eye measurements are often good enough for approximating how large something is. A thumb is often about 10 cm, an arm about 1m.

Mission:
Cooperate in groups of three students. Use uniformity for the triangle with the angle from your eye, and the sides being your thumb and extended arm, to approximate how tall three rather tall objects close to your school are. Trees, light posts or antennas are some examples.

Before heading out, write down the method you intend to use for measuring the heights. This will be used by another group, and you will similarly receive a method from another group. Use their method to calculate the height of the three tall objects. Help each other estimate if your measurements and calculations using the given method are reasonable. When done measuring the three tall objects, write helpful feedback for updating the method. You will then receive your original method with feedback. Update it and use it to measure the same objects again.

Write your reflections here in LoopMe:
- What was the largest source of error?
- Did your measurements get more accurate after updating the method?
- If you were to update the method again, what would you change?

Attachments:
A document with the method before and after feedback, figures and calculations for the objects measured.

Follow-up question: What do you think you have learned from this mission?

Ma3c – Calculus: Interiors & Integrals

Background:
A good working environment is important. Indoor environments and offices need sufficient ventilation. To properly dimension the system, accurate data on the premises volumes is needed. If students or employees can support their claims of poor air quality with data, there is greater chance of change.

Mission:
Part I: Use integrals to accurately calculate the volume of premises that you frequently visit. Draw a simple map or figure that shows what you're working with. Many rooms are simple cuboids, feel free to challenge yourself with more complicated shapes. You may have to split the volume in parts to be able to calculate the total.

Part II: There are policies and regulations for ventilation. The school should have documentation on what is installed on the premises. Find it and compare with your calculations. Present your findings to the school management, the janitor or technicians. Keep in mind that formulas alone do not always persuade.

Write your reflections here in LoopMe:
- Does the calculations you performed support your experience?
- Are there other things in your study environment that could be improved if motivated by similar research using mathematics? How? Describe briefly.

Attachments:
A document with your figures and calculations.

Follow-up question: What do you think you have learned from this mission?

Ma3c – Calculus: Pre-school Integrals

Background:
Small children can sometimes not yet understand that volume is conserved if moved to a different container. Pouring the same amount of liquid to a wide and short glass and to a slim and tall glass, the child may prefer the slim and tall due to the water level being higher.

Mission:
Part I: Start by proving to yourself that the volume is indeed conserved regardless of container. Note that most glasses are not perfectly cylindrical. Use figures to illustrate your measurements and calculations.

Part II: There are policies and regulations for ventilation. The school should have documentation on what is installed on the premises. Find it and compare with your calculations. Present your findings to the school management, the janitor or technicians. Keep in mind that formulas alone do not always persuade.

Write your reflections here in LoopMe:
- Does the calculations you performed support your experience?
- Are there other things in your study environment that could be improved if motivated by similar research using mathematics? How? Describe briefly.

Attachments:
A document with your figures and calculations.

Follow-up question: What do you think you have learned from this mission?

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Write your reflections here in LoopMe:
- Does the calculations you performed support your experience?
- Are there other things in your study environment that could be improved if motivated by similar research using mathematics? How? Describe briefly.

Attachments:
A document with your figures and calculations.

Follow-up question: What do you think you have learned from this mission?

Ma2b – Statistics: Average salary negotiations

Background:
Both employers and employees need to know their wage statistics.

Mission:
A mathematics work interview. Find and note wage statistics for three different professions. Find a classmate who have chosen similar professions. Hold an interview where one of you acts employer and the other potential employee. Only statistical arguments are allowed. The potential employee starts with a claim of "I want a salary of x credits." Write down the arguments used by both sides. Repeat for the remaining two professions chosen, switching between employer and potential employee.

Write your reflections here in LoopMe:
- What statistical measurement do you think is the most important for your future salary? Why?
- How or when can a high salary be negative for someone?
- Does normal distributions have medians? Motivate briefly.

Attachments:
A document with the wage statistics for your chosen professions and the arguments used for each.

Follow-up question: What do you think you have learned from this mission?

Ma1a – Functions: Air humidity and housing

Background:
HVAC and sanitation studies. Indoor air humidity depends on outdoor factors such as meters above sea level, nearby water sources, temperature, and time of year.

Mission:
Create simple models estimating how air humidity depends on at least three different factors. Finding standard values for air humidity is a recommended start. Plot the model functions in graphs. Briefly motivate your choice of constants in text. Discuss your models with someone knowledgeable of indoor air humidity. Does their experience match your created models? Update your models based on what you discussed and write down what you changed.

Write your reflections here in LoopMe:
- Why is indoor air humidity important?
- What other properties of air can be modelled with similar functions?

Attachments:
A document with the created models, their descriptions, and what changes were made.

Follow-up question: What do you think you have learned from this mission?

Kemi 1/2 – Solutions: Hydroponics and nutrition

Background:
A water- and area-efficient way to grow plants is by hydroponics. The plants grow directly suspended in a nutritious water solution without soil. The concentrations of various nutrients vary depending on the plant grown and often need to be kept almost constant. A few market gardens have started to consider selling or using hydroponic systems.

Mission:
Create part of an educational poster or presentation to be used by people interested in starting their own hydroponic plantation. A recommended start is investigating what nutrients, chemicals, or other factors are common for hydroponics. As there are many and often interacting elements, focus on one or a few and instead distribute the work in the class. Questions to answer are what concentration of your chosen chemical is optimal, and how can that concentration be maintained.

Write your reflections here in LoopMe:
- How often do you water plants in your home?
- What are the major chemical differences between hydroponic and soil-based plantations?

Attachments:
A document with your contribution to the educational poster, containing answers to the questions about concentration

Follow-up question: What do you think you have learned from this mission?

Kemi 1/2 or Biologi 1/2 – Solutions and senses: Smelly fish

Background:
Fish also have a sense of smell (olfactory system). How does living in water affect enzymes and receptors in the fish's nose? As a fisher it is not only light and noise that can scare the fish. How should fishing equipment smell to attract more fish?

Mission:
Create a blog post or magazine page for fishers describing how to attract more fish by being the right kind of smelly. The text should include some details on how scents spread in water, how olfactory receptors work in fish compared to land-living animals and how sensitive fish are to some common substances used in bait.

Write your reflections here in LoopMe:
- What animals need the most sensitive olfactory system?
- Why do the fragrance molecules not get stuck in the olfactory receptors?
- How would you set up an experiment to test how sensitive a fish is to a certain scent?

Attachments:
A document with the blog post or magazine page with the requested details.

Follow-up question: What do you think you have learned from this mission?

Kemi 1 – Stoichiometry: Hard to clean

Background:
Laundry rooms provide good examples for everyday chemistry. On detergent packaging it is common to find a recommendation to dose depending on water hardness. How close can you use eye measurement to get that dose? How much of a margin is there to dose less and still get a clean result? An optimal dose would save both environment and money.

Mission:
Create an educational flyer with easy to apply instructions suitable for laundry rooms or homes, describing water hardness, the chemistry of how detergents work, the benefits of an optimal dose and how to find it.

Write your reflections here in LoopMe:
- Where does the surplus of detergent end up?
- How much detergent would you use for an ordinary load of laundry?

Attachments:
A document with the blog post or magazine page with the requested details.

Follow-up question: What do you think you have learned from this mission?

Fysik 1 – Friction: Fast feet

Background:
Active people and other athletes are dependent on suitable friction coefficients between for example the sole and the ground or the hand and the bar. All sports are not material sports, but to gain those final percentages, good friction can be the key.

Mission:
Create and perform experiments for calculating friction coefficients for skin or different shoes against common surfaces in sports. Discuss the results with someone training regularly on the surfaces you have measured. Find an answer to what friction and surface would be optimal for their activity.

Write your reflections here in LoopMe:
- What physics makes a sport a material sport?
- What other forces apart from friction is important for sports?
- How much energy do you lose to friction when moving on an average day?

Attachments:
A report describing the experiment, results, conclusions, and the answer to what the optimal friction and surface would be for the activity of the person you discussed the results with.

Follow-up question: What do you think you have learned from this mission?

Fysik 1 – Electricity: Triboelectric cat boogaloo

Background:
Static electricity is sometimes demonstrated by rubbing fur against an ebonite rod. Animals with fur can also be victims of the triboelectric effect. This can lead to electric shocks for both the animal and the person who tries to pet, fur sticking to objects, or light objects sticking to the fur. Pet owners are now looking for help to avoid electrically charged pets.

Mission:
Write a guide for pet owners that describe what causes and how to avoid electric shocks for pets and owners.

Write your reflections here in LoopMe:
- In what environments are static shocks dangerous?
- Why do you usually not get shocks from the clothes that you are wearing?

Attachments:
A document with a guide explaining reasons for and tips on how to avoid charged pets.

Follow-up question: What do you think you have learned from this mission?

Fysik 1 – Fields: Gravitation vs Levitation

Background:
Maglev trains avoid rail friction by instead having strong magnets repelling the train against gravity. Earnshaw's theorem says that a system with only static permanent magnets is never stable. A common play with magnets is to try to force two same poles together.

Mission:
Design a section for a science centre or similar where elementary-school students can explore and investigate how and when magnetic levitation does or does not work. The stations should be designed for hands-on play, illustrate forcefields and on a suitable level explain why the magnets are stable, hovering or neither.

Write your reflections here in LoopMe:
- Where is the energy lost in a stable maglev?
- How does one stabilize vibrations in a maglev?
- What simplifications were made to help the students understand magnetism?

Attachments:
A document with pictures, descriptions and explanations for your station.

Follow-up question: What do you think you have learned from this mission?

Naturkunskap – Health and scientific methods: Cafeteria

Background:
Food is good. There are many books and pages online with recipes and reviews. What does a number on a scale of 1-5 mean for food? Cafeteria and restaurant chefs are looking for inspiration for both nutritious and tasty food.

Mission:
Perform a study investigating if there are any correlations between the reviews given to a recipe and its ingredients or contents. Start from the question "How much does a certain amount sugar, salt, fat, protein, carbs, or vegetables affect the review score?". Summarize the findings in a table and see if there are any trends. Present and discuss your findings with people who often cook, such as kitchen staff or chefs. Write down at least two of the things you talked about.

Write your reflections here in LoopMe:
- Is there an optimal meal for review scores? For human needs? How would they look?
- What does a score of 4 out of 5 mean in a food review?
- What is the average score for meals that follow the plate model?

Attachments:
A report with a table of studied recipes, their review score, and the notes from discussing with cooks,

Follow-up question: What do you think you have learned from this mission?

Appendix R

Tables with tag usage, answers and reports sorted by emotion.

Table R1 - Number of participating students, feeling score and tag usage from the participating classes for all missions reported.

	Tags used, total	Students	Emotion	Explanations helped	Could explain	Fount information	Meaningful	Contribution	Clear goal	Easy	Challenge	Difficult	Misc/Other
Classes	Kemi 1	23	0,35	22%	9%	13%	22%	22%	9%	35%	17%	17%	22%
	Ma1a	29	-0,41	22%	9%	13%	22%	22%	9%	35%	17%	17%	22%
	Ma1b	95	0,45	24%	4%	15%	11%	19%	8%	9%	31%	36%	22%
	Ma2b	57	0,31	16%	12%	12%	20%	16%	16%	4%	48%	28%	8%
	Teknik 1	12	1,17	25%	8%	25%	33%	17%	58%	33%	25%	0%	17%
	Totalt	**216**	**0,364**	**21%**	**9%**	**12%**	**10%**	**19%**	**10%**	**15%**	**31%**	**37%**	**21%**

Table R2 – Student answers to the question: How can you show the teacher what you have learned?
Table R3 – Student answers to the question: What makes you ask why you need to learn something in school?

	How can you show the teacher what you have learned?	#
Categories	Tests / Exams	25
	Hand-ins / Tasks	18
	Lessons	9
	Discussions / Seminaris / Presentations	7
	Internships	2
	Can not show	1
	”Use what I have learnt”	1
	"[...] descriptive text [...]"	1
	Total Answers	**64/80**

	What makes you ask why you need to learn something in school?	#
Categories	Feels unnecessary	14
	Find future uses	12
	Find relevance / connections	7
	No reason to ask	6
	Feels boring	4
	Not asking - Finds reasons on their own	3
	Not understanding what to do	1
	Total	**47/80**

Table R4 – An overview of some student answers sorted by emotion.

Emotion	2	1	0	-1	-2
Student answers:	It was good and fun with some variation to the lessons. Math easily becomes very black and white and it was fun with something outside the book. If you one does not ask one will not progress with one's education. In the same way as one has questions in one's texts. By tasks like this one.	I learned to take notes for a study and to analyse the results. It was fun to do something new and different from the usual.	I don't know. I did not quite understand the task so I'm not sure if I even did it right .. However it was fun and interesting to discuss the different graphs with my supervisor	I think it was a hassle and complicated and I got demotivated when things did not work and I did not understand since I became irritated and bored then. I would have learned better by the usual maths. However it was good to have some variation in the tasks and working with others.	that there are functions in real life even if they are difficult to find. Bad task if working with elderly people,
	Reflection We discusses and explained for eachother how to solve the task. A chemistry task becomes the right level of challenging when one has to use formulas in many steps to reach an answer. Stochiometry is important for everyone.	We learned to log statistics and used new words. We also argued that the test was not reliable. It was fun but instructions were a bit difficult.	I like the idea for this project, but for me who does not like technology that much, this task becomes difficult because there a lot of technical stuff.	I think learned about how to use the Paint function on my laptop. Also to use it for math in a new way.	I did not like it one bit because I think it is a braindead task that does not help anyone
	I think this has been more fun that doing more theoretical tasks where you are only doing it for the grades. I therefore feel more engaged in the project.	Much more fun than to just work in the book all the time, and it gets easier to learn when it is fun.	One learned to think outside the box. But the task was rather complicated and difficult to understand..	I learned a little of what exbonentioal means and that it is a stupid word because it cant be written orr read properly.	Unclear, we did not understand why we did this
	We learned to cooperate a lot in a group, we got to learn different strategies we have not worked with before. To find a correlation between digits and numbers forexample.	I was sadly only present for the rock-paper-scissors, but I think it was educational and fun with something else than only math.	Did not understand the purpose of what to do with the task	It would have been more enjoyable as I said if I had understood more clearly what to do but I think the idea was fun	How to roll a dice effectively
	It was interesting and fun. It was a bit messy when the webpage did not work but later when it did it was clear what to do.	It was ok, I understood the task today and found some correlations but did not quite see the purpose of the task	It was a bit strange, did not feel like I learned anything	It was confusing. I prefer to work with procedure-tasks where it is obvious what and how to answer.	This app makes me sad
	I think this task was fun, more enjoyable than working in the book. Don't know if I learned anything new directly, but it was fun to try.	Instructions were difficult but I learned that I won more times using paper but that it is mostly random	Unclear how the format would help us understand the correlation	nothing. Unclear. We needed better explanation. Did not get it!	sick and tired of all of it
	I learned what tactic I should use to win against my opponents! :D	I understood after reading the instructions, but did not understand why we were throwing dice.	fun but difficult, fun because it was something new	Nothing, maybe some knowledge of the difficult terms	A>esrtå¨ 'ökjh
	I think this was the best! :D #darechallenges	I enjoyed working towards a goal.	already knew how to calculate median.	not very much, it was difficult and complicated	Very fun
	use paint and read a diagram	it was fun to do something different in class	Am neutral.	interesting but difficult	Difficult
	it has been very nice	Much	What means	dont know difficult	
	hi heLLO	Hi	jwhwu	very good	
	Good	Yes	good	don't know	

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