Thinking like an Engineer

A preliminary investigation into the effectiveness of delivering *Engineering Habits of Mind* in STEM education at my school

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Context

At my school, currently Yrs 7 and 8 are taught a double STEM (Science, Technology, Engineering and Maths) lesson each week. The project work is not assessed / marked, buts form part of a wider school enrichment curriculum; in this case aimed at helping students to appreciate the relevance of, and be able to apply STEM skills in a wider context than the individual subject classes, e.g. to real world situations and scenarios.

I teach Design & Technology, and along with the rest of my department, we are all involved in delivering the STEM curriculum in conjunction with the Science and Maths departments. I am also a member of the STEM change team, whose role is reviewing the current and developing future schemes of work.

For this investigation, the class involved will be a Year 7 STEM class; an entire tutor group of twenty four students of mixed gender and ability. It also continues with the whole school focus on independent, enquiry based learning, and is part of a wider emphasis on improving and refining STEM, including via change teams.

The 'problem' or issue you have addressed

It has been identified that some aspects of the STEM schemes of work are too prescriptive. Consequently, it could be beneficial to present students with more open problems, and / or give them the tasks of initial problem identifying, so see if this gives them better opportunities to develop those problem identifying and solving skills.

Review of current practice and literature

EHoM has been a major part of a recent Inset day at my school, as my school has a particularly strong focus on enquiry learning and how it builds independence. It is also of particular interest to me since much of it is intrinsic to my subject area of Design & Technology. As an NQT, I am

especially seeking to refine my teaching practice, so the opportunity to investigate EHoM was not an opportunity to be missed.

My Research Question

"If I give this STEM class much more ownership of their learning / project by them being much more involved in identifying the problems that they will be investigating and solving, will that result in greater use of problem finding and solving Engineering Habits of Mind (henceforth simply 'EHoM')?"

Part of this will hopefully involve an overall greater use and development of EHoM, leading to deeper student engagement and higher quality outcomes.

The Project

I was delivering this project to two year 7 classes - the first exactly as per the scheme of work to act as a control in terms of outcomes, and the second in a way that was intended to develop students' EHoM skills. It is my intention that some of my evaluation of the EHoM delivery will be based on comparison between the two groups.

Action:

The conventional scheme of work had students working through each topic area week by week as a class. Rather than teaching this project in the conventional and very linear 'This lesson we will do this section / investigate this problem', with all students participating in each topic area, the new scheme will see them selecting a specific topic area that interests them. They will then spend the remainder of the project time working in small teams within their chosen topic area, independently identifying problems and working towards solving them. Not only will they therefore have more time to investigate that topic in much more depth, they will also be spending time identifying the problems themselves, rather than simply being told what the problems are.

Research method:

Assessment / comparison of the effectiveness will include questionnaires for students to self-assess (see appendix for the 'STEM Questionnaire' that was used in addition to the EHoM

'Questionnaire for Students'), and by my own observations of their engagement and the resulting outcomes.

Findings

Results based on teacher observations:

Many students in the class were able to work very effectively within the greater freedoms of being able to identify and choose the problems that they were solving. However, this was far from universal, as there were quite a few who lacked the ability to work effectively within such an open context, for whatever reason. In some cases, I believe that without a much more defined framework it was simply too open for most of those students, but unfortunately there were a few individuals whom I am certain saw this freedom as simply an opportunity to attempt to get away with not doing much work…

I was surprised to see that there was a slight noticeable gender bias (in favour of the female students) in terms of those most inclined to work more independently. However much of this may well have been simply due to the personalities and dynamics within the group. It must also be noted that when it became apparent that no one had chosen one topic area, two of the male students volunteered to investigate that area, and did so with considerable engagement, given that it was not their original choice.

Whilst every group as a whole worked well and remained on task, many successfully identified several interesting problems within their chosen areas entirely by themselves, and certainly having selected these on their own meant that they were fully engaged in their attempts to solve them.

The additional time provided as a result of each group concentrating on just one challenge section of the topic (rather than being required to attempt all of them) meant that each area could be much more thoroughly researched, and there was also much more opportunity to review and re-evaluate their work. This was especially valuable, since when approaching it again in the next lesson (a week later), they would often see things with a fresh mind, and thus identify problems in what they had proposed, or be able to identify better solutions.

Results Based On Outcomes:

Due to the multi-strand manner in which the various research areas were running concurrently and with a group of this size, it was simply not possible for me as the class teacher to devote the same amount of time to each area as when they were being delivered sequentially as per the original scheme of work. This was despite a considerable degree of effort to integrate the delivery of EHoM in a structured manner into the delivery of the project, whilst also providing a appropriate level of support and guidance. Consequently, whilst most students did produce outcomes showing evidence of having used a high level of EHoM, the actual end solutions in terms of the work produced in some cases were less resolved when compared to the group taught in the more structured manner. However, in the situation as outlined in recommendations for future implementation below, I would expect that to be remedied. As it was, the outcomes did display a much greater level of student research and input, as well as being far more student-led due to the difference in project delivery.

Student survey results:

Results of EHoM *Questionnaire for Students* *- carried out at the start of the project.*

Question	Rarely (or never)	Sometimes	Quite often	Very often (or always)
I like making links between things in my head	1	**14**	6	3
I enjoy putting things together to make something new		5	**14**	5
I'll check and check again until I am happy	1	**11**	8	3
I love asking questions and having my own point of view	3	5	**10**	5
I like thinking out loud when I am being imaginative	1	5	8	**10**
I like making models to show my ideas	1	6	8	**10**
I like making what I've done better	2	6	**11**	4
I explain how well I am doing to my teachers or friends	6	**11**	5	2
My brain comes up with lots of good and new ideas		3	**12**	9
I like working in a group	2	5	6	**10**
I stick up for what I think when talking with other people		4	**11**	9
I work hard and practise to get better, even when it's tricky		6	**9**	**9**

As can be seen from the results above, the general trends are already more in favour of EHoM than not.

Results of *STEM Questionnaire* – *carried out at the end of the project.*

	Strongly Disagree	Disagree	Don't Know	Agree	Strongly Agree
I found this STEM project more enjoyable than the one before		3	4	**10**	4
I chose an area to research and problem solve that I enjoy or am interested in		2	6	**8**	4
I prefer to be given a set task to work on	5	1	4	**10**	1
I found the research useful for identifying the problem(s) myself		3	5	**8**	6
I did not expect the problem that I finally identified	1	4	6	**9**	3
I needed more information from the teacher	4	**9**	4	4	1
I prefer to spend more time on solving just one problem and doing it well		1	7	**9**	5
I found it helpful to work independently on this project	3	1	**8**	6	3
I found it useful to co-ordinate with the teams working on the other problems / topics		1	5	**10**	5
I am pleased with the outcome of my research and problem solving			4	6	**11**

(Whilst all students were present on the occasions when the questionnaires were filled in, not all students answered every question.)

The results of the second survey raised some interesting questions. Several of the questions posed were deliberately approaching the same theme but from different angles, in order to see whether the student responses reflected that same viewpoint in both responses. A much more detailed analysis of the results than space here allows would be needed to analyse the answers for individual students in more depth to see if any potential contradictions were actually such, or just simply reflecting the varied views within the group.

One specific aspect that I believe is of particular note is that a distinct majority preferred this project to the previous one. This may of course be due to the different subject matter; however the subsequent answers to the questions suggest that the way the project was delivered contributed to that viewpoint.

Lessons Learned and next steps

Overall, this group did engage well with the much more open approach to the project. There were a few individual students who struggled with that difference, but the vast majority took on the challenge, and used what they had researched and identified to lead the way towards solutions to the problems.

Limitations / issues identified within this action research:

Trying to run the various groups alongside each other whilst providing the same level of teacher support as the conventional method of delivering this project proved to be simply too chaotic in terms of resourcing and lesson structure. For example, one group might be working on an experiment, or constructing a scale model, which would often distract the attention those who were researching or writing up their findings.

This meant that it was not easy to keep tabs on individual student progress, or use structured class time for students to review and reflect (e.g. via self or peer assessment) on the problem, research and solutions respectively that they were working on. Consequently, whilst many students did achieve strong outcomes, my feeling is that with more teacher support and guidance (e.g. scaffolding of skills, especially for creating effective 3D models), they would have achieved even more in terms of the outcomes. This was simply not feasible to deliver that level of teacher support with this year group, number of students and the widely differing nature of the different project areas. Also evaluating the approach and views of the other group using both questionnaires could have provided some useful baseline comparison data.

I believe that an older year group with much more experience of using EHoM in such project work would be better able to work more independently in this situation.

Recommendations for future implementation within the STEM curriculum at my school:

Next year, when the different approach to this scheme of work is rolled out across the year group, in order to eliminate the problems and concerns identified, I am recommending that the scheme of work be re-written and the class structure be reorganised. This would specifically accommodate and assist the delivery of EHoM in a far more central role. It will both build on the strengths I observed, and also address the limitations discovered from the delivery of thepilot scheme used for this action research. My recommendations are as follows:

Rather than members of each class all working in their groups on different topic areas concurrently, instead I propose that the classes should spend the first double lesson researching the wider issue (and by the end, choosing what they want to concentrate on) before students are then split off into specific classes that are then each working on that particular problem area. This will still enable students to work primarily on a topic that interests them most, and the hopefully increased engagement should hopefully bring with it much more successful outcomes within the more open framework necessary for them to be identifying and choosing the problems themselves. However, by each class then being grouped by topic area, this will allow for much more lesson structure and targeted availability of resources and equipment to allow a successful focus on review and improvement via The Design Process, but without detracting from the fundamental EHoM strategies.

Other Comments:

Despite the less than conclusive results from this research, I still firmly believe that EHoM have a central role to play not only in STEM (as per this piece of action research) but also in my normal subject of Design & Technology. In hindsight my feeling is that a Year 7 group may also not have been the best class with which to carry out this research. In contrast, I wonder whether a KS4 Design & Technology class (with its heavily self-selected problem solving emphasis), may have been a much better setting for an effective piece of action research. In particular, the KS4 students' final year projects are predominantly self-directed within a series of briefs provided by the exam board, and would be an excellent demonstration of (previously imbedded?) EHoM strategies in action.

References

Various EHoM sessions delivered by the University of Winchester, and also the associated supporting documentation.

Appendices

In addition to the EHoM 'Questionnaire for Students, below is the questionnaire created for students to feedback at the end of the project.

STEM QUESTIONNAIRE

1 = Strongly disagree
2 = Disagree
3 = Don't know
4 = Agree
5 = Strongly agree

Date……..

Name……. Class……..

1. I found this STEM project more enjoyable than the one before 1 2 3 4 5

2. I chose an area to research and problem solve that I enjoy or am interested in
1 2 3 4 5

3. I prefer to be given a set task to work on 1 2 3 4 5

4. I found the research useful for identifying the problem(s) myself 1 2 3 4 5

5. I did not expect the problem that I finally identified 1 2 3 4 5

6. I needed more information from the teacher 1 2 3 4 5

7. I prefer to spend more time on solving just one problem and doing it well
1 2 3 4 5

8. I found it helpful to work independently on this project 1 2 3 4 5

9. I found it useful to co-ordinate with the teams working on the other problems / topics
1 2 3 4 5

10. I am pleased with the outcome of my research and problem solving 1 2 3 4 5