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Investigating Learner Perceptions and Outcomes of the Flipped Classroom in Foundation Chemistry Classes

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To compensate for the fast-paced, content-driven nature of the Foundation Chemistry module, which is coupled with wide-ranging learner knowledge and backgrounds, a fully flipped approach was introduced for the topics of qualitative equilibria and quantitative kinetics to assess whether this could improve learners' understanding and attainment. Statistical analysis of module and exam marks provides some evidence that the fully flipped approach had a positive impact on attainment for the topic of quantitative equilibria, and the learners' perceptions, as measured through a survey, for this topic confirmed that the flipped model had indeed improved their understanding. However, there is no evidence to suggest any improvement in learner understanding in the more complex topic of quantitative kinetics. After considering both the analysis outcomes and the learner responses to the survey, it is suggested that the flipped methodology be used as part of a mixed methods approach to teaching.

Introduction

Foundation Chemistry is part of a one-year Foundation Science course at the University of Nottingham designed to prepare learners who do not have the necessary pre-requisite science qualifications needed for direct access onto their chosen science degree course. Therefore, the course tends to be fast-paced and content driven to provide learners with the relevant scientific background needed to prepare them for successful progression and to put them on an equal footing with peers who have followed the traditional A-level route. As a consequence, there is little time for learners to develop an understanding of the concepts if these are introduced in traditional-style lectures. Furthermore, learners are often overwhelmed by both the amount of information presented and the challenges associated with some of the complex concepts met. Seery (2015) discusses the problems associated with exposing learners to too much new, complex material in too short a period and how this can inhibit learning owing to the high cognitive load experienced by the learners.

In addition to the pace and content, the cohort of learners who apply for the foundation course have a wide range of abilities and backgrounds, with a significant proportion of overseas learners with English as a second or third language. The work of Bergman and Sams (2012) indicates that a flipped model has the potential to include all learners and that this is because the role of the educator is changed through flipping. By allowing more class time to be spent helping learners, particularly those who struggle the most, it provides an opportunity for the engagement of all learners and not simply the more confident and able who are often the first to raise a hand and ask questions. Therefore, the flipped model approach should encourage a greater level of learner-educator interaction and learner-learner interaction and consequently should be able to accommodate the full range of abilities and backgrounds present within the learner cohort.

Several studies have investigated the positive implications, such as improved attainment, engagement and retention rates of learners, of using the flipped classroom for a variety of chemistry courses (e.g. Eichler and Peeples, 2016; Fautch, 2015; Flynn, 2015; Hibbard et al., 2016; Seery, 2015; Shattuck, 2016; Weaver and Sturtevant, 2015). Eichler and Peeples (2016) and Shattuck (2016) have both reported that there was a significant improvement in learner attainment when using a flipped approach compared to non-flipped. Shattuck (2016) also noted that the overall withdrawal rate from the flipped course was reduced, and learners felt more confident in the topics using flipped pedagogy compared to the topics where the traditional lecture-based format were applied.

Fautch (2015) found that using video lectures as a homework activity and introducing problem solving activities in class led to increased comprehension and confidence with the material, with fewer withdrawals from the course. It is not clear, however, that there was an increase in attainment as although the number of A grades did increase, the number of B grades decreased with a significant rise in C grades. Could this simply represent benefits for the more able and conscientious or indeed simply be a difference in the cohorts involved? A similar conclusion was made by Flynn (2015) where analysis of the grades and retention rates obtained for a cohort of learners exposed to a course using the flipped model of learning were compared to previous years. Again, high learner satisfaction was evident and although the findings show improved grades and decreased withdrawal rates compared to the same courses from previous years, it was not possible to conclude that using the flipped classroom model caused these improvements due to the many individual learner differences that exist from one cohort to the next (Flynn, 2015).

Indeed, Seery (2015) highlights that the evaluation of the educational impact of flipped learning is unclear when simply investigating the grade achievements of different cohorts of learners and that these should be used with caution. It is suggested that a more individual analysis of learners may provide more useful and valid information as to the impact of flipping the classroom (Seery, 2015). Research conducted during Ryan and Reid's (2016) year-long parallel controlled study of the flipped classroom provides some support for Seery's (2015) suggestion. While there was no overall difference in attainment between flipped and control groups, by separating the cohorts into three separate ability groupings from pre-test data, exam performance was found to improve for the bottom third of the cohort in the flipped model.

Methodology

The Flipping Process

A fully flipped approach was employed for two topics: qualitative equilibria and quantitative kinetics. These topics were selected because previous cohorts had struggled to answer exam questions well. Learners were often confused with predicting the change in yield associated with an equilibrium when the external conditions of the reaction are altered, and many struggled with the calculations associated with reaction kinetics. To reduce the associated confusion and lack of understanding, instead of a traditional lecture format, learners were provided with pre-lecture material that they were able to work through and digest at their own pace. This was then followed up with more interactive problem-solving activities and group work in class instead of traditional lecture format. Unlike other studies where video lectures are used, the pre-lecture material provided here comprised either a Moodle (the virtual learning environment (VLE) used at the university) lesson that not only provided the necessary theory on the topic, but also included more interaction (Eichler and Peeples, 2016; Seery, 2015) through animations and questions, or a fully animated PowerPoint slideshow comprising theory and questions. This was done to avoid the passive retrieval of information that could be associated with a research or reading task, and to give learners the opportunity, and time, to reflect on their own understanding of the material they have accessed. In addition, worked examples were incorporated into the pre-lecture material which provided a link from the theory to the in-class activities (Seery, 2015).

The in-class sessions were focused around either collaborative group work in a learner centred active learning environment, similar to activities discussed by Weaver and Sturtevant (2015), or problem solving where discussion between learners is actively promoted. In addition, there was also the opportunity for individual activities to ensure all learners took responsibility for their own learning as well as learning from discussions with others. Example activities include:

- Each learner in a group had responsibility for and had to explain one of the key learning points to the rest of the group using examples to illustrate their explanations, e.g. in quantitative equilibria this would involve the concepts of Le Chatelier's Principle, the effect of concentration, pressure and temperature. Example responses were then fed back to the whole class from each group.
- Providing a problem that learners answered individually in the first instance and then shared their responses in a group discussion. The group then had to decide collectively on the most suitable response.
- An online multiple-choice quiz was provided through Socrative that included explanations after each question, thus allowing learners to work individually and reflect on their own understanding after the previous activities.
- Workshop style problem solving where learners were provided with a problem sheet and could work individually or discuss different problems within their groups.

During the session, the role of the educator became that of a facilitator; this enabled learners to ask more questions and engage more with the topic material.

Learner Surveys

After completing the flipped activities, the cohorts experiencing the flipped methodology (2016-17 and 2017-18) were asked to complete an on-line survey. Prior to completing the survey, learners were informed verbally of why such activities had been developed, i.e. to aid their understanding, confidence and application of knowledge, and also to investigate whether the use of a flipped learning approach has a positive impact on learning and attainment. Learners were then given access to an online anonymised survey and asked to complete it if they wished to take part in the study.

The survey was designed to obtain feedback regarding the online pre-lecture material and to identify the learners' perceptions of how the activities impacted on their learning and understanding. The questions used were based on previous work carried out by Fautch (2015) and Smith (2013). A four-point Likert-type scale was used in which learners were able to agree or disagree with statements on a scale of 1 to 4 corresponding to: 1 – Strongly agree; 2 – Agree; 3 – Disagree; 4 – Strongly disagree. The survey was limited to fifteen questions so that learners did not have to spend too much time completing it. There was the opportunity for further open-ended comments if the learners wanted to provide additional feedback on their experience of the flipped approach.

The survey design and data collection process (both survey and achievement data) were approved by the institution's ethics procedure.

Attainment Analysis

Overall module marks and exam question marks relating to the two topic areas where flipped learning was employed were analysed to identify whether there were any significant differences in the attainment of the cohorts that could be attributed to the flipped learning experience. The learners were categorised initially into year groups to carry out a general comparison of each year cohort and then into learning type categories for the two topics identified.

The learning type categories included: No Engagement (NE), defined as no attendance at the relevant lecture/classroom session and no engagement with online pre-lecture materials (all cohorts 2014 to 2017); Traditional Lecture (TL) (cohorts 2014-15 and 2015-16); Fully Flipped (FF) where learners engaged with on-line pre-lecture material and attended the classroom session (cohorts 2016-17 and 2017-18); and Part Flipped (PF) defined as completing either the on-line pre-lecture material or attending the classroom session but not engaging with both elements of the fully flipped experience (cohorts 2016-17 and 2017-18).

Shapiro-Wilks normality tests were carried out on the module and exam question data collected to identify the most suitable inferential statistical analysis between the cohorts being compared. To account for the non-normality of some of the distributions of exam data being used, nonparametric Kruskal-Wallis tests were carried out for comparison of the attainment of the different cohorts. Where significant differences are determined, Mann-Whitney U pairwise tests with Bonferroni corrections are used to identify between which cohorts the differences exist. The effect size, η^2 (Lenard and Lenard, 2016), is also presented to provide an indication of the importance of any differences.

The descriptive statistics of module marks and relevant exam marks for each category and a summary of the initial Kruskal-Wallis statistical analysis results are provided in Table 1.

Cohort Comparison

As it was not possible to do a direct comparison of the learners embarking on the foundation course because of their widely varying academic and cultural backgrounds, the overall module marks were compared to see whether there was any significant statistical difference between the four cohorts. The descriptive statistical information obtained from the overall module mark for the four cohorts shows very little variation across the year groups (Table 1 and Figure 1). This is reinforced by the Kruskal-Wallis test resulting in a p-value > 0.05 which illustrates no statistically significant difference between the module outcomes for the four cohorts.

Given that each cohort had experienced the same course content, structure and educator it is therefore reasonable to assume that the distribution of ability and backgrounds across the four cohorts are comparable.

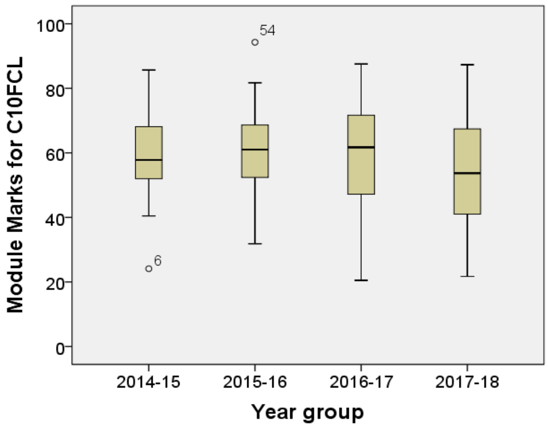

Figure 1. Box plots illustrating the distributions of the foundation chemistry module marks for each year group. Note: The error bars show the full range of marks not including any identified outliers, indicated by numbered points. Lower outliers are defined as being lower than Q1 – 1.5 x IQR and upper outliers are defined as being greater than Q3 + 1.5 x IQR, where Q1 and Q3 are the 1st and 3rd quartiles and IQR is the interquartile range.

Qualitative Equilibria Analysis

The overall module marks and the marks associated with the qualitative equilibria questions for the four learning categories were compared through the same statistical analysis as the year cohort module marks. Figure 2(a) represents the descriptive statistics for the different learning categories and combined with a p-value of 0.180 (Table 1) the analysis suggests that there is no significant difference across the different learning model categories for the whole module attainment. However, Figure 2(b) illustrates a potential difference in the equilibrium exam marks achieved across the four learning categories and the Kruskal-Wallis analysis returns a p-value of < 0.05 (Table 1), suggesting a significant difference does indeed exist between the attainment of the learners in these four different learning categories.

Further pairwise Mann-Whitney U statistic tests for two independent groups (with a Bonferroni correction) suggest that this difference is attributable to significant differences between not only the NE category with all other categories, but also between the TL and FF categories (Table 2). Therefore, not only is there, unsurprisingly, evidence that a lack of engagement with a topic will result in lower attainment, but also a suggestion that the flipped method of learning enhanced the attainment of the fully flipped category of learners. The effect size for each of the significant differences identified are also reported in Table 2 and all lie in the range of effect sizes that Lenard and Lenard (2016) interpret as the '*zone of desired effects*' for effective learning after Hattie (2007).

Data set	**Cohort**	**N**	**Mean**	**SD**	**Min**	**Max**	**Shapiro-Wilks *p*-value***	**Kruskal-Wallis *p*-value&**
Overall % module mark	2014-15	24	58.9	13.4	24.1	85.7	0.791	0.540
	2015-16	33	60.4	13.7	31.9	94.3	0.914	
	2016-17	44	58.7	16.8	20.5	87.5	0.237	
	2017-18	39	55.1	16.5	21.7	87.3	0.612	
% module mark for equilibria learning categories	NL	9	49.0	19.8	21.7	81.5	0.554	0.188
	TL	52	59.6	13.3	24.1	94.3	0.755	
	FF	61	59.8	16.1	20.5	87.5	0.251	
	PF	16	53.7	16.1	29.1	76.6	0.168	
Qualitative equilibrium E1 question % marks	NL	9	12.9	12.8	0.0	40.0	0.125	0.000
	TL	52	41.0	30.8	0.0	100	0.005	
	FF	61	59.5	35.4	0.0	100	0.000	
	PF	16	53.5	23.2	16.7	100	0.889	
% module mark for kinetics learning categories	NL	18	44.3	12.8	20.5	68.1	0.852	0.000
	TL	50	60.7	13.6	24.1	94.3	0.636	
	FF	41	61.8	16.1	21.2	87.5	0.125	
	PF	31	57.1	14.9	29.1	87.3	0.465	
Quantitative kinetics E2 question % marks	NL	18	21.5	27.0	0.0	90.7	0.002	0.007
	TL	50	54.7	30.6	0.0	100	0.007	
	FF	41	49.9	37.5	0.0	100	0.000	
	PF	31	47.1	35.0	0.0	100	0.007	

Table 1. Descriptive statistics and Kruskal-Wallis analysis of the overall foundation chemistry module marks and qualitative equilibrium and quantitative kinetics exam marks for each of the identified year or learning category cohorts.

*The test rejects the hypothesis of normality when the p-value is less than or equal to 0.05.

& A p-value < 0.05 means that the distribution of marks is significantly different across the cohorts.

Data set	Pairs	N	Pairwise *p*-value[&]	Effect size, η^2
Qualitative Equilibrium E1 question	NE vs TL	61	0.066	-
	NE vs FF	70	0.000	0.177
	NE vs PF	25	0.000	0.577
	TL vs FF	113	0.030	0.070
	TL vs PF	68	0.492	-
	FF vs PF	77	1.000	-

Table 2. Mann-Whitney U pairwise analysis of the qualitative equilibrium exam marks for each learning category. [&] *p*-values have been adjusted using the Bonferroni correction; a value < 0.05 means that the distribution of marks are significantly different across the categories.

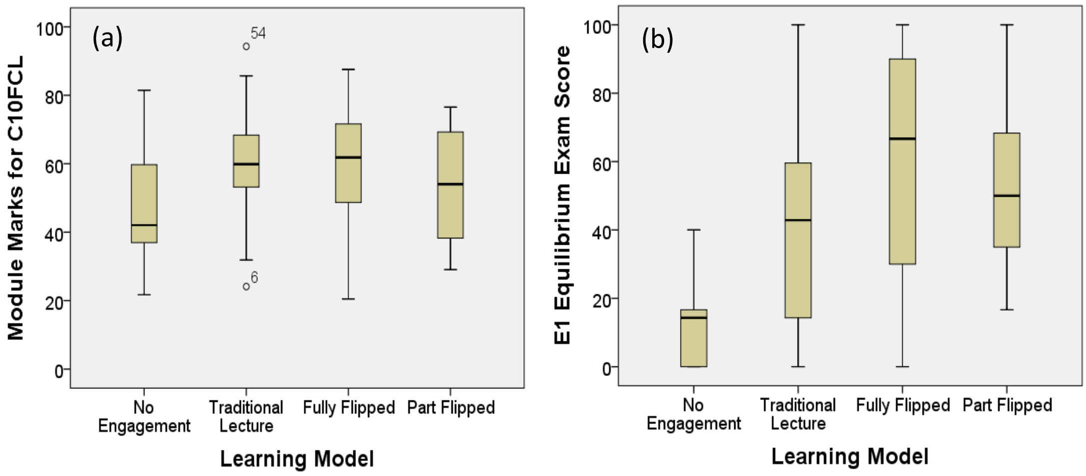

Figure 2. Box plots illustrating the distributions of the (a) foundation chemistry module marks and (b) qualitative equilibrium exam marks for each learning type category. Error bars and outliers are determined as described in Figure 1.

Quantitative Kinetics Analysis

The same analysis carried out for the qualitative equilibrium topic was applied to the quantitative kinetics topic. Figures 3(a) and 3(b) represent the descriptive statistics for the overall module marks and the kinetics exam question marks for the four different learning categories. The Kruskal-Wallis tests return *p*-values of 0.000 and 0.007, respectively (Table 1), suggesting that there is a significant difference across the different learning model categories for the whole module attainment and the kinetics exam question marks.

Further pairwise Mann-Whitney U statistic tests for two independent groups suggest that this difference is only attributable to significant differences between the NE category with all other categories for the overall module mark, and only the NE category with the TL category for the kinetics exam question marks (Table 3). Therefore, for what is often perceived as a more complex topic because of the mathematical elements involved, there is no evidence to suggest that the flipped method of learning enhances the attainment of learners.

Data set	Pairs	N	Pairwise *p*-value[&]	Effect size, η^2
Module mark for Kinetics Categories	NE vs TL	68	0.000	0.244
	NE vs FF	59	0.000	0.237
	NE vs PF	49	0.036	0.158
	TL vs FF	91	1.000	-
	TL vs PF	81	1.000	-
	FF vs PF	72	1.000	-
Quantitative Kinetics E2 question	NE vs TL	68	0.000	0.193
	NE vs FF	59	0.054	-
	NE vs PF	49	0.054	-
	TL vs FF	91	1.000	-
	TL vs PF	81	1.000	-
	FF vs PF	72	1.000	-

Table 3. Mann-Whitney U pairwise analysis of the quantitative kinetics exam marks for each learning category. [&] *p*-values have been adjusted using the Bonferroni correction; a value < 0.05 means that the distribution of marks are significantly different across the categories.

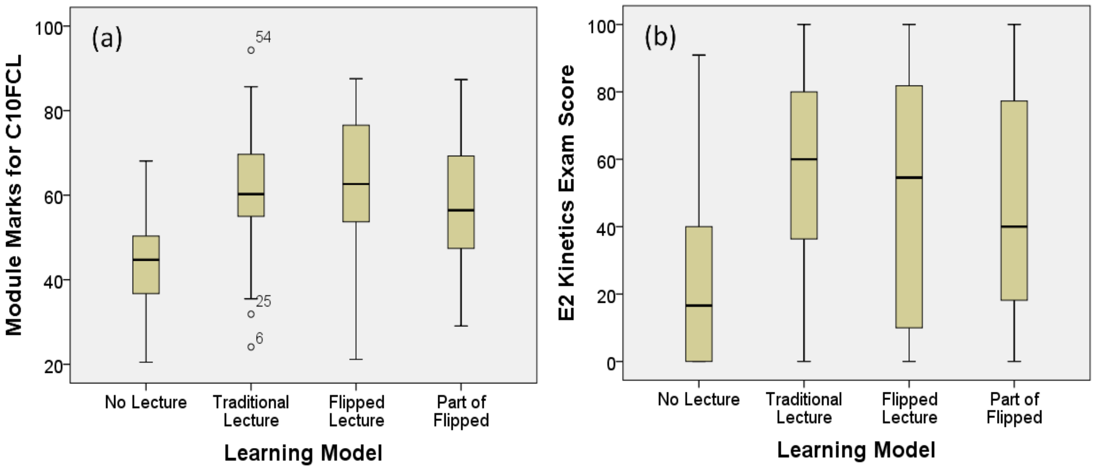

Figure 3. Box plots illustrating the distributions of the (a) foundation chemistry module marks and (b) quantitative kinetic exam marks for each learning type category. Error bars and outliers are determined as described in Figure 1.

Learner Perceptions

The learner survey was carried out after completing the first flipped session on qualitative equilibria. The responses to the fifteen questions are presented in Figure 4 and illustrate an overall positive response to the learner experience in engaging with the flipped learning model, both in terms of the structure of the learning (Q1 - Q7, Q15) and the learner perceptions of the impact on their own learning and understanding of the topic (Q8 – Q14). A question was included to gauge whether learners found the pre-lecture material burdensome in terms of time (Q5) and if they were negative towards the idea of pre-lecture work. Most disagreed or strongly disagreed and therefore were generally positive about the preparation work (Figure 4).

Example responses include:

> "I found the class room activities to be useful because they enabled me to share my understanding with others and I was able to learn a particular topic in a different way by listening to others."

> "I like the idea of preparing for the lecture in advance. It is time consuming, but it is a great way to be familiar with the learning material. I would like to experience it more often."

> "I do find them useful, but don't think for every topic - especially the harder ones. A mixture is good as you end up doing the same amount of work before or after the lecture either way. However it can be tricky if someone hasn't done it!!"

> "Pre-learning the lecture material makes understanding the lectures much easier. Working through problems together gives confidence in answering questions in an exam style. Socrative quizzes are wonderful at re-enforcing knowledge."

> "I find if we cover a lot of material in a lecture, I have to re-listen to the lecture several times afterwards to fully understand, because of this I find it hard to engage in questions/activities in the normal class setting. With the flipped learning, I can go through the pre lecture at my own pace and come to the lecture knowing I fully understand the topic!"

> "The classroom activities are useful but I would prefer learning the material in the Lecture and asking questions throughout rather than doing the material at home and asking questions later on."

> "I probably prefer normal teaching method but this style may be useful for some topics. I like the online pre lessons but would prefer them to be optional additional to the normal lesson rather than instead of."

Table 4 presents the main themes identified from the open-ended responses received with the most common response involving a positive impact on improving understanding in the lecture and having support whilst problem solving in the classroom session. Some learners identify that they personally prefer learning in the traditional lecture format, and these tended to provide the negative responses illustrated in Figure 4.

Main Points	Occurrences[&]	%
Improved understanding in lecture	7	30%
Positive on support during problem solving	5	22%
Prefer traditional model	4	17%
Pre-lecture material confusing	2	9%
Prefer mixture in class of lecture and problems	2	9%
Not for more difficult topics	1	4%
Possibly for more difficult topics	1	4%

Table 4. Summary of the main themes identified from the open-ended comments section of the learner survey. [&] N = 83 (total number of learners experiencing flipped learning) with 61% (51 learners) completing the survey and 45% (23 learners) submitting open-ended comments.

Although there was no survey linked to the flipped quantitative kinetics topic, several learners referred positively to the value of completing on-line pre-lecture material in the end of module evaluation, but it was noted that occasionally a learner did not understand the work as well as other non-flipped topics.

Figure 4: Horizontal bar chart illustrating the proportion of positive and negative responses to the survey questions. In all questions except Q5, 'Strongly Agree' and 'Agree' have been identified as positive responses and 'Strongly Disagree' and 'Disagree' have been identified as negative responses. For Q5, 'Strongly Disagree' and 'Disagree' are identified as positive responses and 'Strongly Agree' and 'Agree' are identified as negative responses. (Note: Q1 is located at the base of the bar chart and Q15 at the top.)

Conclusions

There is some evidence that using a fully flipped model of learning can improve learner attainment in a simple topic such as qualitative equilibria where the previously identified confusion can be addressed using more student focused activities. However, there is little evidence of a significant improvement in attainment for a more complex topic such as quantitative kinetics, a potential issue identified in the learner responses to the survey. This may be an area where partial flipping could be implemented effectively, enabling learners to become familiar with a topic through providing selected key information prior to the classroom session and following this with a mixed session of lecture and student focused activities. This builds in the time to have whole class discussions whilst complex theories are explained through a traditional lecture format but also enables learners to apply their new knowledge through learner focused activities. Indeed, the learners identified through the survey and through the end of module evaluation the benefits of a mixed methods approach in learning.

For both topics analysed there is clear evidence that engagement is crucial for learners to achieve their potential as in all cases the learners classified as NE achieved significantly worse than their peers. Reassuringly, those that engaged partially with the flipped process were still able to achieve to a similar level as those that attended traditional lectures and those in the fully flipped category.

Factors that could impact on this analysis and require further investigation are links to the individual academic abilities of the learners involved and the timing of the topics in the academic year. It was noticeable that the engagement with the pre-lecture material was lower with the kinetics topic at the end of semester 2 compared to the equilibrium topic in the middle of semester 1. It should also be noted that no credits were associated with completing any of the activities, although direct links to exam performance were made.

Although attainment is often used to provide a measure of the success of flipping the classroom, and has suggested mixed results for different learners, it is not only attainment that is important. A positive response from the learner to the learning experience is pivotal to their development and a greater emphasis on learner-centered, problem-based activities will likely benefit learner overall, even if there is no significant improvement in exam performance.

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