The Impact of Using Formula Sheets for Physics Examinations

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1. Introduction

Most people would agree that physics is a tough subject, a perception which is confirmed by the high failure rates. For example, Beichner et al. (1999) found that only about 50% of 1,288 US students successfully passed introductory physics courses in one university. Similarly, Poulis et al. (1997) analyzed the physics performance of over 2,500 tertiary students in Europe during 1979-1992 and concluded that only 55±15% succeeded. Many students may concur that it is the complexity and abstraction of physics formulas which make the subject so challenging. In order to improve students' performance in examinations and to encourage meaningful learning, the author adopted the strategy of using a formula sheet (FS) in physics exams.

1.1 Literature Review

The literature has debated the pros and cons of using FS in physics examinations. Moses (2000) argued that FS may give students an excuse not to study and will thus eventually reduce exam scores. Rehfuss (2003) argued the possible drawbacks of using FS in physics exams, including that it 1) implies that math manipulation is more important than conceptual thinking, 2) encourages students to make an encyclopaedic survey of the content rather than seeking in depth understanding, 3) hinders students' understanding of complex phenomena, and 4) by reducing memorization, may lead to instructors covering too much material.
On the other hand, Cone (2003) advocated the potential benefits of adopting FS, including 1) lessening the tension of exams, 2) organizing an FS helps students internalize the key concepts, and 3) allowing better and more meaningful test construction. Hammed's (2008) study found that 1) preparing an FS can force the students to spend more time studying prior to the exam; and 2) the process of preparing an FS can help the students organize their physics concepts.

1.2 Methodology

The context is a tertiary introductory physics course for engineering students. Two years of implementation and evaluation of the strategy were undertaken. The instructor provided the students with a blank table to fill in, then allowed them to bring this FS to the examinations. Three research questions were investigated:
- Which type of questions mostly benefited from the students using an FS?
- How were the FS related to individual students' performance in the examinations?
- How did the students perceive the advantages and disadvantages of using an FS?

To answer the three questions, this study 1) compared the students' examination performance with and without FS; 2) ranked the quality of each student's FS, based on its thoroughness, and evaluated the Pearson correlation coefficient between the exam scores and the FS rankings; and 3) invited 216 students to fill in a questionnaire survey, including quantitative ratings and qualitative comments.

2. Results

2.1 Examination Performance with formula sheets

The performance in exams of the students with FS and their counterparts without FS were compared. Table 1 shows that the group with FS outperformed those without FS in seven out of the nine questions. The Chi-square test found that three questions were significant at prob. < 0.05.

Table 1: Percentages of correct answers with/without FS, types of questions and the chi-square test

	1a	1b	2a	2b	3a	3b	3c	4a	4b
With FS	42%	18%	53%	74%	75%	20%	10%	67%	50%
Without FS	26%	7.6%	49%	60%	51%	19%	5.7%	75%	51%
Questions Types[&]	SM	CH	SM	SM	FT	CH	CH	CN	SM
χ^2 test	4.93*	3.76	0.37	4.98*	16.3**	0.26	1.07	1.83	0.04

&: SM: simple manipulation; CH: challenging questions; FT: factual knowledge; CN: conceptual
*: prob.<0.05; **: prob.<0.001

The question type for which the students benefited the most from using FS was factual knowledge, i.e., #3a: adiabatic constant r =1.4 for diatomic molecules. The second most effective question type was that which required only simple manipulation of formulas, i.e., #1a and #2b. In addition, challenging questions (#1b, #3b, #3c) appeared to benefit slightly from FS when comparing correct percentages, but the effect was statistically insignificant. For example, #3b requires complex and unfamiliar mathematical skills of exponential manipulation, and # 1b and #3c both entail multiple step derivation. Lastly, the only question on which the FS group had inferior performance was a pure conceptual question (#4a) relating to identifying an adiabatic process as Q=0.

2.2 Quality of formula sheets and scores

The correlation of the quality of individual students' FS and their examination scores were also evaluated. Based on the completeness of the essential formulas, five levels of FS quality were adopted, rated 5 to 1, then the correlation coefficient between examination score and rank of FS was evaluated. Table 2 shows that the correlation coefficient was r =0.461. Thus, the quality of FS seems to be beneficial to each individual student's performance in the examination.

Table 2: Student distribution of examination scores and quality of formula sheets (n=50)

Examination scores distribution		FS quality distribution		Correlation between exam scores and FS quality
scores	# of stud. (%)	ranks	# of stud. (%)	
>80	12(24%)	5	4 (8%)	
70~80	12(24%)	4	12 (24%)	
60~70	16(32%)	3	18 (36%)	r = 0.461
50~60	7(14%)	2	15 (30%)	
<50	3(6%)	1	1 (2%)	

2.3 Students' attitudes towards adoption of formula sheets

The quantitative results of the students' attitudes towards the FS policy are listed in Table 3.

Table 3: Percentages of students' agreement/disagreement with adopting formula sheets

Classes (# of students)	agree	neutral	disagree
2009 A (n = 53)	92%	3.8%	3.8%
2009 B (n = 52)	88%	12%	0
2010 A (n = 57)	86%	14%	0
2010 B (n = 54)	80%	16%	3.8%

Most of the students possessed positive attitudes towards the FS policy. The responses among the 4 classes were fairly consistent, with 80%~92% of the class members agreeing and less than 4% disagreeing.

2.4 The advantages of using formula sheets

The students' comments in the open-form questionnaire survey were interpreted. First, the students acknowledged that making up their own FS can facilitate understanding of the whole concepts. For example,

In order to make up my own FS, (I) need to review all the content completely and acquire understanding.

Preparing the FS helped me integrate the key concepts again before the examination.

Second, many students recognized that FS not only reduces the loading of memorization, but also highlights the importance of thinking or conceptual clarification. For example,

FS can avoid the trouble of memorizing formulas, since knowing how to use (formulas) is more important than reciting.

I agree, since physics examinations should focus on understanding and application, not memorization.

Third, FS may help students answer questions and ease the stress of sitting examinations. For example,

FS is just like a tranquilizer which can also inspire me during examinations.

We need to really understand what we jot down on the FS in order to extract the suitable formulas in the exam.

In sum, the advantages of adopting FS include cognitive, affective, and even meta-cognitive aspects. Since FS reduced the students' loading of memorization and eventually improved their performance in the exams, using FS allows the instructor to raise the cognitive demand when designing examination questions.

2.5 The disadvantages of using formula sheets

In addition to the favorable comments regarding the FS policy, a few students (0~3.8% of each class) expressed their concerns about reliance or fairness. For example,

I disagreed, since we would get used to relying on the FS and would ignore many of those formulas which should be memorized.

The professor can provide us with a unified FS, since making up our own FS can be controversial.

3. Conclusion

In sum, the policy of adopting FS in physics exams was found to enhance the students' learning commitment as well as improve their performance in examinations, especially the question types of factual knowledge and simple manipulation. This finding contradicts Moses (2000) and Rehfuss' (2003) assertion. Meanwhile, the quality of each student's FS seems to have a positive correlation with individual performance in exams. The students' comments indicated rather favorable attitudes to the strategy. Preparing their own FS may facilitate understanding of the whole content. In addition, while most of the students acknowledged that FS can reduce the memorization demand and ease their stress during examinations, the strategy seems to have a constructive impact on the students in terms of their appreciating the importance of thinking and conceptual comprehension. Therefore, the FS strategy may appear to cut down the need for memorizing formulas, but it actually promotes the cognitive demands of the examinations, and encourages more meaningful learning of physics, in line with the notions of Cone (2003) and Hamed (2008).

References

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