CHEMICAL ENGINEERING AND MODULAR INSTRUCTION: A STATUS REPORT

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THE CHEMI PROJECT, supported by the National Science Foundation and the Cache Corporation, is attempting to produce over 350 single-topic, stand-alone modules spanning the entire undergraduate chemical engineering curriculum. The project is now about two years old; one-third of its modules are completed to at least first-draft stage. This was chosen as an appropriate time, having demonstrated the feasibility of developing such an ambitious set, to gather implementation and dissemination data from the professors of ChE who are the potential "brokers" of these modules.

The ASEE (American Society for Engineering Education) sponsors, with industrial support, a summer college of its Chemical Education (ChEd) Division once every five years. This past summer such a one-week college was run; two members of every department of ChE in the country were invited. Approximately 200 persons chose to attend. This group was representative of ChE education in attitude and geographic distribution. It was decided to use this opportunity to:

- **acquaint or reacquaint these engineering educators with the CHEMI Project, and**
- **obtain attitudinal and potential implementation feedback for the project. As each attendee registered on the first day, he was handed a letter and brief questionnaire, a list of the full anticipated modular set, and a sample module. Instructions were to go through all the material and return the questionnaire within a day.**

On the whole, the results were extremely encouraging. 115 questionnaires were handed out; 61 persons returned completed questionnaires or approximately 52% of those who had received them. The results of the survey were tabulated and then presented briefly at a session the following day, serving as a basis for further discussion and refinement of the findings. Thus, this survey, although based on a small sample (N = 61), yielded findings that are broadly representative and are fairly encouraging regarding the use of CHEMI-type modules in undergraduate instruction. The opportunity to discuss the findings during the meeting itself was well received and resulted in added insight into, or clarification of, some responses.

FINDINGS

THE INVESTIGATORS were particularly interested in the relationship between previous exposure to modular materials (as a student or as an instructor) and perceived implementation advantages and disadvantages in their use. There were a few interesting differences:

Previous Exposure to Modular Material

34 Yes	26 No	1 Blank
(52%)	(46%)	(2%)

The respondents were fairly evenly divided as to their previous exposure, indicating the possible need for this project and other module development efforts to undertake more hands-on and informational/instructional work about the teaching method. The sophistication of *all* the respondents about modules, in response to later questions, was very high, however; even those who had not used them could list many alleged benefits and drawbacks and apparently had some informed basis for their opinions.

One question asked: "How likely might you be to use modules such as the one provided and those listed in the following situations?" Responses are listed below:

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TABLE 1
Likelihood of Module Use

	Previous Experience			No Prior Experience			Totals		
	1*	2*	3*	1	2	3	1	2	3
Supplement to Text	25	6	0	22	3	0	45	9	0
Replace Texts	0	8	23	0	6	18	0	14	41
Replace Lectures	5	14	10	2	10	11	7	24	21
Additional Practice	23	5	3	20	4	0	43	9	3
Remediation	16	13	2	18	4	3	34	17	5
Acceleration	14	12	4	15	9	0	29	21	4
Individualized Programs	18	11	2	12	10	2	30	21	4
Resource for Preparing Lectures	1	1	1	18	7	0	19	8	1
Totals**	102	70	45	107	53	34	207	122	78

Other
(Recertification 2)
(Examination Preparation 2)
1* = Very likely
2* = Perhaps
3* = Not likely
**Totals indicate likelihood of module use in any way listed.

In general, module users as well as those without previous exposure held similar opinions, i.e.:

- **Modules were most likely to be used as supplements to texts, for additional practice, for remediation, for acceleration, and for individualized programs;**
- **Modules were not likely to be used to replace texts.**

Even more important, in inspecting the data in this table, is the fact that perceived likelihood of module use, for the entire range of purposes listed, is strongly supported both by those with and without previous modular exposure. Without saying that modules can be a panacea for all teaching-learning problems, the respondents were uniformly and strongly positive about the variety of applications listed, with the exception of text replacement.

Other uses which respondents suggested on their own were the use of modules for recertification (or continuing education) and for "stealing" or "quality preparation" of examinations.

The only area where there was a striking difference between those with module experience and those lacking it was the item "Resource for Preparing Lectures." Those without experience uniformly felt modules could be a useful resource; those with experience uniformly did not feel they could be used that way. Further discussion of this issue indicated that many professors not acquainted with modules had thought the "hour's length" could be a pre-packaged lecture.

The next question involved the preference of respondents for module availability, allowing for

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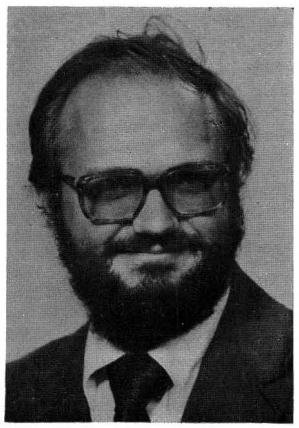
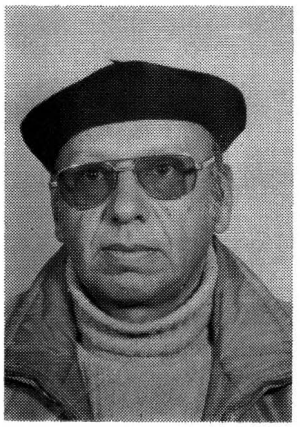
Karen C. Cohen is primarily interested in educational evaluation and graduate science and engineering. She received her B. A. from Harvard and M. A. and Ph.D. from Johns Hopkins University. She is currently on the faculty of M. I. T. with a joint appointment in ChE and the Div. for Study and Research in Education. Part of her work involves co-directing Project PROCEED (Program for Continuing Engineering Education). She also directs the Center for Educational Research and Development at WPI. The author of several books of evaluation strategies and evaluation reports, she was a consultant to the effort reported here. (C)

Professor Ernest J. Henley has been a professor of chemical engineering at the University of Houston, since 1964. He received his Ph.D. from Columbia University in 1953 and has been on the faculty of Columbia University and Stevens Institute of Technology. (R)





only two options: to purchase sets of individual modules or single modules with reproduction rights.[4] The preference seemed to be for single copies with rights to reproduce them:

TABLE 2
Ordering Preference

	1st Choice	2nd Choice	3rd Choice (other)
Order one copy with right to reproduce	32	8	2
Order sets	12	18	0
Other	2	1	0

Concomitant with preference for in-house reproduction was the nearly universal (all but 1 respondent) feeling that costs of such reproduction could be recovered from students. The modal response was that recovery of costs would be "fairly easy to do."

TABLE 3
Recovery of Reproduction Costs

	N
Cannot	1
Very Difficult	10
Some Effort	16
Fairly Easy	28
Don't Know	2
Other	0

The responses, taken together, while they do not compare modules with other possible modes of instruction, seem to indicate that ChE professors see modules as an additional, valuable resource for a variety of purposes. They would probably like to own (or have available) the entire CHEMI set to use when, where, and in those quantities they see fit. Recovery of in-house reproduction costs does not appear to loom as a large problem.

When professors were asked to list topics in addition to those planned for the project which they would like to see developed, a very small number of suggestions were made. Generally, the entire undergraduate field seemed to be considered covered.

Finally, we were interested in the advantages and drawbacks respondents saw in modular use

- for the student,
- for the teacher, and
- for the administration.

The most striking finding involved the variety in the responses. It was nearly impossible to develop meaningful coding categories for these open-ended questions that would capture, without forcing, the essence of more than two or three responses. The complete array of responses to each item appears below. Probably the most important result of this survey is the fact that one set of materials, these single topic CHEMI modules, is seen as potentially meeting a large number of diverse needs for a large number of people.

More specifically, the following *advantages* were cited:

TABLE 4
Perceived Modular Instructional Advantages

	Previous Exposure	No Exposure	Total
a) For the Student			
Self-pacing	10	9	19
Motivation	8	1	9
Acceleration/fuller coverage	5	4	9
More perceived structure/ better presentation	6	1	7
Supplement to lectures	3	0	3
Efficient review/remediation	2	0	2
Avoid problem of not knowing prerequisite	2	0	2
Good introduction	0	2	2
Same instruction for all	1	0	1
No lecture requirement	1	0	1
Easier learning	1	0	1
Organized to individual needs	0	1	1
Rich variety	1	0	1
Easy availability	1	0	1
Helpful for project work	0	1	1
Clear definition of objectives	0	1	1
Better understanding	0	1	1
Don't have to copy notes	1	0	1
Make up missed lectures	1	0	1
Less formal than books	1	0	1
Minimum cost	1	0	1
A new way to learn	1	0	1
TOTAL	47	21	68
	Previous Exposure	**No Exposure**	**Total**
b) For the Teacher			
Broader coverage	6	0	6
Crutch	0	6	6
More time for 1:1 help	3	2	5
Another view presented	4	0	4
Same presentation to all students	2	0	2
Course planning aid	0	2	2
Make-up assignments	0	2	2
Back-up, lecture replacement	0	2	2
Remediation	1	1	2
Transfer learning responsibility to student	1	0	1
Acceleration	1	0	1

[4]Far more detailed questions were asked of college mathematics instructors regarding such options with results available privately from William Walton, Director, Project Calc, EDC, 55 Chapel Street, Newton, Massachusetts.

Extra instruction	1	0	1
Less preparation time	1	0	1
Cover more effectively	1	0	1
More current	1	0	1
Turn lectures to discussions	1	0	1
Easier feedback	1	0	1
Thoroughness	1	0	1
TOTAL	25	15	40

Without saying that modules can be a panacea for all teaching-learning problems, the respondents were uniformly and strongly positive about the variety of applications listed, with the exception of text replacement.

Responses regarding administration advantages were meager, and are not reported for that reason.

In the same vein, the following *disadvantages* were cited:

TABLE 5
Perceived Modular Instructional Disadvantages

	Previous Exposure	No Exposure	Total
a) For the Student			
None	7	6	13
Impersonal (lack of contact with professor)	3	2	5
Mastery feeling, only crutch	0	3	3
Unfamiliar method	2	0	2
Level of material varies	2	0	2
Without care can become fragmented	1	0	1
Continuity	1	0	1
Some students go slower	1	0	1
Not every student will succeed	1	0	1
Inconsistent nomenclature	1	0	1
Must include references to fill gaps	1	0	1
Harder to use as future reference	1	0	1
Different presentations from each author	1	0	1
Allows student to procrastinate	1	0	1
"Spoonfeeding"	1	0	1
Poor reproduction	1	0	1
Quality below text	1	0	1
Less interaction	1	0	1
Too many sets of paper, hard to keep together	1	0	1
Lock & key simplistic approach	1	0	1
More may be expected of student	1	0	1
Easy to fall behind	0	1	1
Some students respond negatively	0	1	1
Cost	0	1	1
Faculty use carelessly	0	1	1
TOTAL	31 (—7 None = 24)	15 (—6 None = 9)	46 (—13 None = 33)
b) For the Teacher			
None	6	6	12
Modules not synchronized	9	1	10
Modules are a "crutch"	0	7	7
More teaching time, planning	2	1	3
Impersonal	1	1	2
Less chance to explore	1	1	2
Author's personality is too strong	1	0	1
Too dry	1	0	1
Texts are easier to use	1	0	1
Hard to get all modules to students	1	0	1
Hard to tell students have learned	1	0	1
Suppress superiority and innovation	1	0	1
Danger to expect too much	1	0	1
"Continuous contact with bitching students"	1	0	1
Lack of contact with students (if desired)	1	0	1
Hard to tell	1	0	1
Unfamiliar method	1	0	1
Difficult to "time up" the lectures to program of the class	0	1	1
May be superficial	0	1	1
Students procrastinate	0	1	1
TOTAL	30 (—6 None = 24)	20 (—6 None = 14)	50 (—12 None = 38)

Again, administration drawbacks cited were sparse and relatively trivial.

These comments indicate that the professors responding see far more advantages than disadvantages to modular use for students. The fact that the most frequently written "drawback" for both teachers and students was "None," and far outweighed any other perceived drawback (except lack of "synchrony" for those with previous exposure), indicates an openness, interest, and willingness to experiment with modules. Indeed, in the general discussion about the CHEMI Project and the results of the survey, there was disappointment expressed that the entire set was not available immediately both for examination and for use. In addition, the general tenor of the totally open ended comments (Question 8, other

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C'_3 is converted into the mole flowrate C_3 (moles/min) by using the equation:

$$C_3 = C'_3 \frac{(P-P_{H2O})}{R\,T_a} \qquad (9)$$

where R is the gas constant, T_a is the ambient temperature at which C'_3 has been measured, P_{H2O} is the vapor pressure of water at T_a and P is the pressure of the carrier gas.

While the parameters C_1, C_2 and C_3 can be preselected and kept constant for a series of experiments, the ratio $\alpha = \frac{A}{n_s}$ has to be determined by calibration.

To calibrate the apparatus i.e. to determine α, a known amount of a sample dispensed from a syringe (can be determined by weighing) is injected into the system and a corresponding response is recorded. The response area is measured by means of an integrator, or other suitable method.

RESULTS AND DISCUSSION

THE MAIN ADVANTAGE of the described method is its simplicity and relatively short experimental time. However the method has certain limitations, and its success depends on the degree of a dynamic equilibrium achieved in the "cold" column and on the precision of calibration.

To assure the equilibrium vapor pressure of the investigated sample, low flowrate of carrier gas and a relatively long, small diameter column should be used. The amount of sample has to be large enough to assure that a substantial portion condenses in the empty column. However, it is important that the instantaneous sample concentration in the carrier gas always lies within the concentration range of the linear response of the detector. Thus the method is limited to liquids with low vapor pressures at the temperatures used.

For calibration, a wider range of sample size should be used to verify the constancy of the α factor.

The vapor pressure data determined at different temperatures can be fitted to either the Clausius-Clapeyron equation:

$$\log P_s = A - \frac{B}{T} \qquad (10)$$

or to the Antoine equation:

$$\log P_s = A' = \frac{B'}{t+C} \quad (t = °C) \qquad (11)$$

depending on the particular liquid.

To verify the method, we have chosen dicyclohexyl and cyclohexylbenzene. For dicyclohexyl the data were fitted to the Clausius-Clapeyron equation and the parameters A and B were determined by using the least squares method:

$$A = 8.21, B = 2712.8$$

The correlation coefficient of this fit was $r^2 = 0.9997$. The cyclohexylbenzene data were fitted to the Antoine equation and the following parameters were obtained:

$$A' = 7.562, B' = 2162.0, C = 223.5$$

In this case the correlation coefficient was $r^2 = 0.998$. These results agree very well with those obtained by other methods [1]. □

REFERENCES

1. J. A. Riddick and W. B. Bunger, "Organic Solvents", 3rd Edition, Wiley-Interscience (1970).

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comments) conveyed general high hopes and expectations for the project and enthusiastic anticipation for its products.

SUMMARY AND CONCLUSIONS

THE BRIEF SURVEY, administered to the entire ChEd college sponsored by the ASEE (attended by representatives of most institutes and universities where ChE is taught), was returned by over 25% of those receiving it. The survey indicated that participants held a fairly uniform view of the value of modular materials for remediation, acceleration, self-pacing, individualization and more thorough coverage of topics. In brief, they were thought to be a marvelous resource. Respondents who had had previous experience with modular materials (about 50%) had more specific opinions than those without such experience (hardly a striking finding). But the general tone, the serious nature of the comments, and the thoroughness of responses indicates a real concern with teaching effectiveness, and hope and expectation that the completed set of CHEMI modules will be able to improve teaching effectiveness in a variety of ways. □