

## **Build As You Go: An Approach to Completing Laboratory Reports**

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## Introduction

In the fall 2015 offering of a junior-level bioengineering signals and systems laboratory, students were encouraged to submit three written progress reports for each of three projects they were working on to receive feedback and guidance from the instructor. Our course emphasized open-ended problem solving with associated technical report writing, as advocated by the *Writing Across the Curriculum* (WAC) movement (Young & Fulwiler, 1986; Yalvac et al., 2007; Calvo & Ellis, 2010). To our great satisfaction, we observed significant improvement in written report scores upon using these progress reports as well as upon providing additional timely feedback in-between projects. These progress reports prompted each group to explain their proposed solution, provide justification for it, display graphs, ask questions and raise potential concerns, and in general report on project progress. In general, formal academic writing requires analytical thinking and the development and support of an argument about a problem or question (Bean, 2011). In fact, the writing process is a *learning* mechanism, helping to promote students' thinking skills and clarification of ideas (Bean, 2011).

The progress reports were intended as a feedback and communication mechanism between the groups and instructor; they were not mandatory or graded and were returned to the students within 24 hours. Written progress reports and reviews are one means to demonstrate to students that writing is a *process* that occurs in stages (Beason, 1993). To this end, we implemented the *build-as-you-go* approach during the fall 2016 semester. During the 2015 semester, we had noticed a preliminary relationship between students' engagement with the progress reports and their achievement on the projects and had observed that progress reports became a *build-as-you-go* tool for some groups, prompting them to write snippets of the final report as they progressed with their analysis. Thus, during the fall 2016, progress reports were also intended for providing feedback from the instructor, but additionally, they were to be used as a stepping-stone to completing final reports. Students were encouraged to write snippets of their final report as they advanced through various parts of a project and incorporate feedback/suggestions received from the instructor to fine-tune each snippet. The goal was to have the final report go through multiple revisions before it was ready for final submission.

In support of our instructional approach, we uncovered a host of articles in the literature that aligned with the feedback, revision, and build-as-you-go writing strategy and process used in our laboratory course. For example, a *Progressive Paper* was used in a chemistry capstone course, in which students wrote a large laboratory report in sections, resulting in a complete paper at the end of the semester (Van Bramer & Bastin, 2013). The students received detailed feedback after each section, which they could use to revise the section as well as apply it to future sections. Breaking the laboratory report into parts and spreading the work out demonstrated to students how to keep the project manageable. Coinciding with this, the successive draft submissions showed significant score improvements over time, and the students and instructors valued the experience. In fact, teaching a *process* approach to writing can support students in becoming professionally competent writers; such an approach often prompts for writing in draft stages and responds to or intervenes with each draft as required, demonstrating to students that writing

should take place over time, in part to gain better control over the process (Fulwiler, 1987b; Bean, 2011).

As a second example of the alignment of our approach with that of others, the teaching of higher-level writing skills, including synthesis and argumentation, in one upper-level biomedical engineering course was done using an interactive coaching approach. One of the main lessons learned was that writing must be assigned with sufficient time for students to receive feedback, reflect, and revise (Yalvac et al., 2007). Thus, feedback must be well-timed, and if it is, students will be more likely to write effectively (Yalvac et al., 2007). In line with this conclusion, at the Colorado School of Mines (CSM), a process was put in place to improve the struggling written communications portion of a six-week required summer field session for chemical engineers. CSM's process was actually quite similar to ours in that there was a 24-hour turnaround on drafts submitted by student teams, with a subsequent longer time period to incorporate written and oral comments into the final laboratory report (Olds, 1994). Faculty were pleased with the new process, reporting improvement in writing skills, decreased time needed to grade the final report, and less frustration. Students liked the written-communications instruction as well, ranking their satisfaction at 3.95 on a five-point scale. In fact, multiple articles in *The Journal of Chemical Engineering* have stressed (in concert) the importance of sufficient time for review and revision to improving technical writing skills (Gragson & Hagen, 2010).

In a similar manner, engineering instructors have also used journaling to provide feedback on students' progress and drive deeper learning (Sharp et al., 1999). With journaling, students can write frequently in a non-threatening situation and pose questions (in writing) on their difficulties, and the instructor can provide written comments and/or answers to posed questions and monitor student progress (Sharp et al., 1999). In general, journals drive process-focused writing, enabling students to collect information before developing the final product, document outstanding questions, express concerns to the instructor, and in general think as they go along (Fulwiler, 1987a). Thus, we are using progress reports in our laboratory course with similar goals held by other STEM instructors who have used journaling or progressive papers.

## Methods

The laboratory details have been described in a previously published paper (Clark & Mahboobin, 2016). For completeness, a brief description is provided here. As part of a junior-level bioengineering course in biological signals and systems, our laboratory, which met weekly for 50 minutes during the 2015 and 2016 fall semesters, was conducted using elements of both flipped instruction and problem-based-learning. After the preliminary sessions dedicated to MATLAB overview and specifically designed exercises (flipped instruction), students completed three team-based projects, or *virtual* laboratories, in which they conducted experiments using MATLAB to analyze unknown systems, both biological (human balance) and non-biological (bandpass filters), through the use of time- and frequency-domain analysis techniques (problem-based-learning). Each team had the opportunity to submit three progress (i.e., design) reviews per project. These progress reviews prompted each team to explain its proposed solution, provide an argument or justification for it, display graphs and figures, ask questions and raise concerns, and in general report on project progress. The progress reviews were neither mandatory nor

graded and were intended as a feedback and communication mechanism between the students and instructor.

During the 2016 fall semester, however, students were formally instructed on using a *build-as-you-go* strategy for writing each project report. This strategy encouraged them to use the optional progress reports (three per project) as portions of the final report, thus encouraging proactive and incremental writing as the project progressed. During the previous 2015 fall semester, students had *not* been formally instructed on this approach, although some teams determined on their own to use such an approach (Clark & Mahboobin, 2016).

Since the progress reports and build-as-you-go approach were not mandatory, one of our main research questions centered on whether the students were in fact using them and whether they viewed the progress reports as stepping-stones. Individual student interviews were therefore conducted to assess students' use of and perspectives towards the progress reports and build-as-you-go approach. The assessment analyst talked with individual students during scheduled class meetings between October and November in the semester. Approximately 30% of the enrolled students were interviewed. The following questions in Table 1 were posed to the students:

**Table 1: Student Interview Questions**

1	Do you feel you are using the progress reports as a stepping-stone to completing the final project report, and/or are you using the build-as-you-go strategy suggested by your instructor? Please explain or expound upon your use of these.
2	Have your other instructors or courses used these types of techniques (progress reviews with quick feedback or build-as-you-go) when written reports are required?

We performed a content analysis of the responses from question #1 to examine students' use of the progress reports and build-as-you-go approach. Two coders were involved in the content analysis, and the responses were double-coded. One of the coders was the assessment analyst for the project and the other was a senior-level engineering student. We calculated our first time inter-rater reliability, which indicated strong initial agreement, with Cohen's  $\kappa = 0.77$  (Norusis, 2005).

Our coding scheme is described and defined in Table 2 and was developed using a grounded, emergent qualitative analysis of the students' responses (Neuendorf, 2002). Four categories pertain to reasons for, benefits of, or details surrounding use of the progress reports or build-as-you-go approach. These benefits have been advocated in the education literature as helpful for problem solving, professional skills, and teamwork skills (Felder & Brent, 2016). The last two categories pertain to reasons for potentially not using these approaches.

To obtain instructor feedback and triangulate our findings, the assessment analyst interviewed the instructor at the end of the semester using a semi-structured interview protocol, with questions that aligned with the investigative goals (Boulmetis & Dutwin, 2011).

**Table 2: Coding Scheme for Student Interview Responses**

<b>Description/Definition</b>	<b>Category</b>
<b><i>Using Progress Reports or Build-as-you-Go: Reasons or Benefits</i></b>	
Not working at or waiting until the last minute; drives proactivity with the final report	PROACTIVE
We receive feedback; feedback is helpful; direction is provided or expectations are clarified or clear; course corrections are possible	FEED DIRECTION
Copy/pasted or compiled from the progress report to the final report; decomposition or breaking into parts, possibly lessening burden or stress; simplification of the process	PARTS
Pressure is low; progress report is not graded	LOW PRESS
<b><i>Not Using Progress Reports or Build-as-you-Go: Reasons</i></b>	
Obtained face-to-face feedback or help instead of (or in addition to) using progress reports; in-person help or instruction is sometimes necessary or better	F2F
Plan to use progress reports or build-as-you-go in the future	PLAN TO

## Results

Since the students were not required to write the progress reports and did not (per se) have to apply the build-as-you-go strategy to their writing, one of our overarching questions centered on whether the students in fact viewed the progress reports as stepping-stones and/or used the build-as-you-go strategy. Based on the student interviews, to our great satisfaction, they did. In fact, the very great majority of students (96%) indicated they used the progress reports as a stepping-stone and/or applied the build-as-you-go strategy. The one student who answered *no* to question #1 (Table 1) indicated that he planned to use the progress reports in the future to drive proactivity, although he had sought face-to-face feedback from the instructor in writing the first report.

We were pleased to learn the students' perspectives or viewpoints on these techniques. Upon content-analyzing students' explanations for their use of the progress reports or build-as-you-go approach, including the benefits and reasons, the top category cited was the helpful feedback and direction they received, including clarifications and possible course corrections, as mentioned by 72% of those interviewed. Over half of the students (56%) felt these strategies enabled decomposition of the project report into more manageable or simplified parts, including the ability to compile the final report incrementally, possibly via copy and paste from the progress reports. One third of students (32%) recognized that these techniques drive proactivity and reduce procrastination and last-minute work. Despite the prompt written feedback available via the progress reports, 16% still mentioned the desirability of face-to-face instructor feedback as well, which was still a welcome finding. Thus, our overall approach accommodated various

interaction styles, including in-person as well as written. Finally, a small percentage of students (8%) liked the low-pressure aspect of the progress reports, especially the fact that they were not graded. Thus, as desired, the students recognized (in themselves and in conjunction with these approaches) the development of certain professional engineering behaviors and skills.

To directly assess project report performance associated with the build-as-you-go approach, we compared the scores for projects 1 through 3 for those teams who submitted at least two (out of the three) progress reports per project during the 2015 and 2016 semesters. Completing at least two of the three progress reports per project indicated reasonable potential engagement with the build-as-you-go strategy. Recall that the students were formally instructed on the build-as-you-go approach during the 2016 semester (as opposed to the 2015 semester), although the projects were nearly the same between 2015 and 2016, with a difference only in the unknown (i.e., black box) system that the students were analyzing. The grader (i.e., instructor) was the same during both semesters, and he used a rubric to evaluate the projects.

As shown in Table 3, we did not find a significant difference between the 2015 and 2016 (build-as-you-go) project scores for those teams who engaged with the progress reports for a given project. Based on the Mann-Whitney test, which is the non-parametric version of the independent-samples *t*-test, there were no significant differences for any of the projects ( $p \geq 0.15$ ). The Cohen's *d* effect sizes were small for projects 1 and 2, although the effect size was large for project 3 in favor of the 2015 semester. The Mann-Whitney test was used given the smaller sample size (Norusis, 2005). Cohen's *d* indicates the practical, or substantive, significance of a difference, with values below 0.50 considered small and values of 0.80 or above large (Cohen, 1987; Sullivan & Feinn, 2012). When the data were aggregated across the three projects to increase the sample sizes and allow for more power, the difference in average score for 2015 versus 2016 was also not significant, based on a *t*-test ( $p=0.12$ ), and Cohen's *d* was small ( $|d| = 0.38$ ). A comparison of the 2015 versus 2016 cohorts in terms of their average pre-course GPA showed there to be no difference in prior achievement between them ( $p = 0.79$ ).

**Table 3: Project Scores (teams w/ 2+ progress reports/project)**

Average Project Score (/50)	2015	2016 (Build-as-You-Go)	Sample Size (2015/2016)	Cohen's $ d $	Mann Whitney
Project 1	43.9	42.6	11 14	0.35	0.32
Project 2	47.3	46.5	14 14	0.28	0.31
Project 3	48.9	46.5	7 11	0.84	0.15

The scores in this table are for those teams who submitted two or more progress reports per project

Thus, the average project score was not higher or significantly different for the build-as-you-go (2016) group compared to the 2015 group. This was not an entirely surprising result given the

amount of scaffolding and feedback provided to the students during both semesters. Also, the sample sizes were small; therefore, we plan to collect more data to study the relationship further. However, as discussed previously, the students identified professional behaviors and skills that resulted from the build-as-you-go approach that may not have been reflected in the project scores and which were the ultimate goals of the instructor in incorporating *build-as-you-go*. The instructor indicated during his post-course interview that the students in general used the build-as-you-go approach for all projects, and he believed the students' response was encouraging for this first implementation. In fact, he estimated that about 43% of the teams consistently used build-as-you-go after project 1, taking advantage of the suggested formatting approach to structure their progress reports (e.g., partitioning the progress report into introduction, methods, etc. sections), and often directly copying and pasting the critiqued snippets into their final report as recommended.

When asked the second question about the use of these techniques (i.e., progress reports with quick feedback or the build-as-you-go approach) in other courses, approximately half of the respondents indicated that although they had encountered approaches involving instructor feedback and scaffolding previously, it was *not* to the extent, degree, or helpfulness encountered in this course, given the frequent progress reports and subsequent quick feedback. Interestingly, one-quarter of respondents drew good analogies to methods they had encountered in other courses, such as the encouragement of *fast failures* in an *Art of Making* course, weekly quizzes or intermediate exams to drive accountability for content, and senior design/capstone project management. Thus, our approach appears to have been unique for this group of students.

## **Discussion and Conclusion**

Our progress and final project reports required critical thinking and writing, in which students drew and justified conclusions and arguments over time, elucidated assumptions, synthesized information, and presented questions regarding uncertain items. In general, writing assignments help students to think critically and creatively and promote deep learning (Brent & Felder, 1992). Our project reports were designed to mimic the format of a short research article, e.g., an extended abstract. As such students were presented with the *suggested* approach of using each progress report to build toward their final report, but they were free to adopt other ways to utilize the progress reports to build the final project. In the instructor's assessment, given this comparatively open or free approach, it was very reassuring to observe that almost all groups used a form of the build-as-you-go approach in each project and that it only took one project cycle (i.e., project 1) before about half of the groups consistently started appreciating and utilizing the benefits of the build-as-you-go strategy and the suggested format.

Although at this preliminary juncture we did not uncover a significant difference in project scores between the 2016 (build-as-you-go) and 2015 groups, and considering the fact that the build-as-you-go strategy was somewhat unique to the 2016 cohort and implemented for the first time in our laboratory course, the students' response to this strategy was nonetheless very encouraging. In fact, based on course evaluations conducted at the end of the semester, students responded positively to this approach and indicated that it helped them approach their problem solving in increments by utilizing the progress reports as a stepping-stone to the final project report. In addition, the students interviewed identified helpful feedback and direction,

problem/project decomposition, and proactivity as top benefits of the progress report and build-as-you-go approaches, which were professional skills that the instructor was targeting with the approach.

In conclusion, and based on the results gathered during 2015 and 2016 semesters, we believe that the combination of scaffolding in general (Clark & Mahboobin, 2016) and our specific scaffolding approach of build-as-you-go report writing has been successful in enhancing the open-ended problem solving and professional skills of the students participating in our laboratory. We also view our build-as-you-go approach beneficial to students partaking in senior capstone projects in which project duration may last for up to two semesters and therefore require incremental writing. We plan to continue with the build-as-you-go approach in subsequent semesters and will interview students who are currently enrolled in a follow-up course that uses laboratory experiences to illustrate principles taught in several bioengineering core classes such as our signals and systems course. These interviews will be done to gauge content retention and assess if students are continuing to utilize the build-as-you-go approach introduced in the laboratory portion of our course.

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