Title: Active reflective learning by wiki - Experiences from first year to doctoral level at KTH

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Background and purpose

A novel learning activity, in which students create exercise problems and solutions (of another student) on a wiki page, has been implemented in a number of courses in numerical analysis for the past years. The aim of the wiki activity is to stimulate students to interact with the material in a deeper way, more characterized by creativity and playfulness than when solving given problems on their own. The courses also contain lectures, homework, videos and quizzes, and the wiki activity is not intended to replace any of these. It provides additional student-teacher (and student-student) interaction within the subject. The technique has been used in courses ranging from bachelor level, to master and PhD level.

Finished work/ongoing work

In the first-year course, *SF1547 Numerical Analysis*, with about 250 students, each section of the class (with about 60 students) has its own wiki page. Experiences show that when it works well students answer each others' problems and help each other. Exposing their work to classmates and teachers seems to motivate students. The questions and solutions posted by students are coupled to the topic of the week. They are moderated, and each post is checked by teachers or teaching assistants. If necessary, a dialogue is initiated so the student can make corrections. Towards the end of the course, a selected set of questions are marked as appropriate for exam preparation and distributed in a separate PDF-file. As it is implemented in this course, the wiki activity works as a stimulus for the stronger students. Contributing to the wiki is voluntary and gives bonus points that can only be used for reaching one of the higher grades (A or B), never for reaching the passing grade (E). About half of the students attempt producing wiki questions. The others spend their time on other activities, e.g. the homework and quizzes, and they can still benefit from using the selected questions as exam preparation.

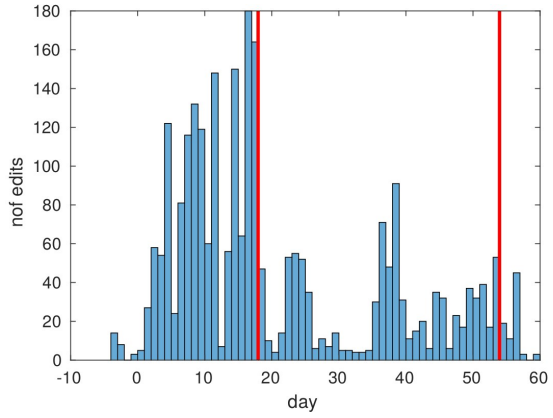
The master-level course *SF2524 Matrix computations for large-scale systems* and the PhD level course *SF3580 Numerical linear algebra* are taught partially jointly with a common wiki. Approximately 30 students attend, including doctoral level students who are required to do additional work on the wiki. In particular the PhD students have been very enthusiastic producers in the wiki activity, e.g., since it allows the freedom for them to relate the contents of the course to their research area. This seems to have considerable value also for master students. The student-student interaction between master and

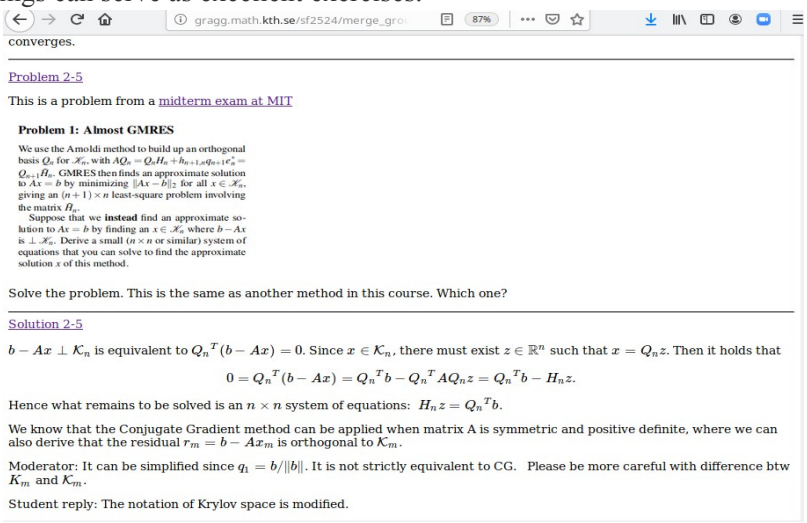
PhD level students makes the master students see that the gap between research and education is not insurmountable. The same setup has also been used in the master course *SF2526 Numerics for data science* and the PhD level course *SF3584 Preconditioning for linear systems*.

Technically, we use our own server with small scripts (written in PHP) which provide an interface to CANVAS (via the REST API) where all the edits are made and stored.

Results/observations/lessons learned

Our observations indicate a positive effect on the learning, as indicated by comparison between different courses that do not use this technique. The students tend to spend time on this task continuously throughout the course; see figure. According to the course analysis, the technique has increased genuine interest in the material. Another positive factor is that the activity provides a natural way to incorporate material from other universities (see figure with problem from MIT) making the result feel more relevant and meaningful, and even increase self-confidence. Videos produced by others and wikipedia entries are naturally connected to the course as errors / shortcomings can serve as excellent exercises.




converges.

Problem 2-5

This is a problem from a midterm exam at MIT

Problem 1: Almost GMRES

We use the Arnoldi method to build up an orthogonal basis Q_n for $\mathcal{K}_n$, with $AQ_n = Q_n H_n + h_{n+1,n} q_{n+1} e_n^* = Q_{n+1} \tilde{H}_n$. GMRES then finds an approximate solution to $Ax = b$ by minimizing $\|Ax - b\|_2$ for all $x \in \mathcal{K}_n$, giving an $(n+1) \times n$ least-square problem involving the matrix $\tilde{H}_n$.

Suppose that we **instead** find an approximate solution to $Ax = b$ by finding an $x \in \mathcal{K}_n$ where $b - Ax$ is $\perp \mathcal{K}_n$. Derive a small ($n \times n$ or similar) system of equations that you can solve to find the approximate solution x of this method.

Solve the problem. This is the same as another method in this course. Which one?

Solution 2-5

$b - Ax \perp \mathcal{K}_n$ is equivalent to ${Q_n}^T(b - Ax) = 0$. Since $x \in \mathcal{K}_n$, there must exist $z \in \mathbb{R}^n$ such that $x = Q_n z$. Then it holds that

$$0 = {Q_n}^T(b - Ax) = {Q_n}^T b - {Q_n}^T A Q_n z = {Q_n}^T b - H_n z.$$

Hence what remains to be solved is an $n \times n$ system of equations: $H_n z = {Q_n}^T b$.

We know that the Conjugate Gradient method can be applied when matrix A is symmetric and positive definite, where we can also derive that the residual $r_m = b - Ax_m$ is orthogonal to $\mathcal{K}_m$.

Moderator: It can be simplified since $q_1 = b/\|b\|$. It is not strictly equivalent to CG. Please be more careful with difference btw K_m and $\mathcal{K}_m$.

Student reply: The notation of Krylov space is modified.

Take-home message

From a course development perspective, the wiki exercise has, as a side-effect, provided deeper insight into the student learning process. The additional viewpoints provided by the students have helped us make improvements in the course in general. The development of course material has accelerated. Most notably, the exam questions now have a higher variation (less "typtal" character) and provide a better examination of the course aims. The teacher and teaching assistants now have a repertoire of more and better explanations of certain concepts thanks to the wealth of ideas provided by students in wiki problems.

References

[1] Publicly available wiki of the course SF2524/SF3580 Matrix computations: http://gragg.math.kth.se/sf2524/merge_group_pages2.php?name=97069