Flipped learning with a formative assessment in the development of physics and math conceptual understanding

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Abstract. The successful adaptation and implementation of flipped learning, a form of blended learning, currently supported worldwide by the Flipped Learning Global Initiative (http://flglobal.org/), strongly depends on the effective mixed application of digital technologies. We present several formative assessment techniques using free digital technologies in the frame of the flipped math and physics education at higher education level. Our results from various case studies indicate not only better-prepared, motivated students for more complex activities during the face-to-face part of flipped learning but also better conceptual understanding and ideas about fundamental mathematical and physical concepts.

1 Flipped learning in math and physics education

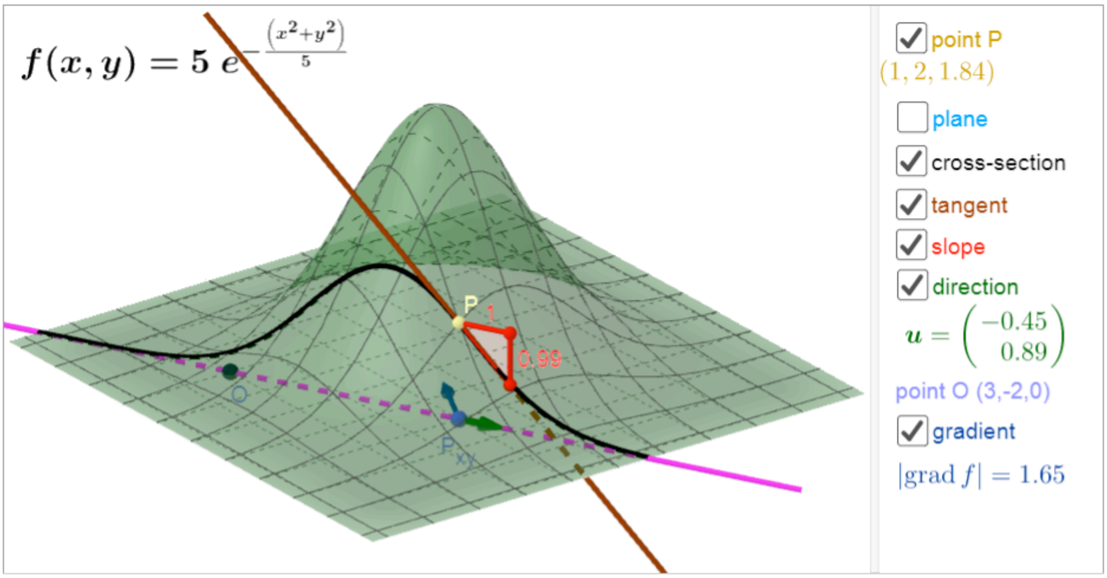
The flipped learning, a special type of blended learning, combines effectively a student's individual online multimedia pre-class instruction with an in-class face-to-face student-teacher active-learning dynamic interaction. Since the beginning of 21st century, the flipped learning has evolved into many forms [1, 2]. In math and physics education, it is the well-known Eric Mazur's flipped Harvard physics classes whose pedagogy draws on interactive teaching methods: just-in-time teaching, team-based learning and peer instruction [3].

The flipped learning as an adequately applied educational strategy gives evident benefits to both teacher and students, e.g. extra free in-class time for more complex applications of concepts and knowledge, stronger motivation or avoiding information overloading [1, 4]. Current worldwide flipped learning pedagogical adaptation and implementation supported by the Flipped Learning Global Initiative (http://flglobal.org/), brings not only growing evidence of its effectiveness but also new pedagogical and research questions caused by itself [4]. e.g. what assessment tools can replace the teacher's absence as a self-regulating mechanism providing immediate feedback to students during pre-class preparation; what typical difficulties are faced by students in that case.

2 Formative assessment techniques and free digital technologies

In our flipped math and physics introductory courses [5] at our University, we integrate formative assessment inspired by [6, 7] with various free interactive digital technologies such as Google Drive connected cloud apps [8] (e.g. Google Classroom, Forms, Docs, Sheets, EdPuzzle, Lino, Kami, Geogebra) and web-based Sage and Jupyter notebooks [9]. Especially interactive computing Jupyter (or Sage) notebooks, which can be freely installed locally or provided by cloud environment COCALC (https://cocalc.com), enable to use, modify or create shared documents including live code (now we use Sage – open CAS based on Python), interactive simulations, plots, images, equations, narrative texts, annotations or videos (Fig.1).

Combining with formative assessment techniques - automatically graded self-assessments (Google Forms), Google docs or Kami pdf digital annotations, narratives or two-minute papers, such interactive computing notebooks allow students to learn, develop and express their ideas, thinking and results or calculations from own experimentation with key mathematical and physical concepts (more pedagogical details will be presented in the conference talk and full paper).

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In [1]: # calculation of the directional derivative in the direction u (or OPxy) via rules
        f(x,y) = 5*exp(-(x^2+y^2)/5); O = vector([3,-2]); Pxy = vector([1,2])
        u = (Pxy-O)/norm(Pxy-O); gradf = f.gradient()(1,2); dfdu = gradf*u
        u.n(), norm(gradf).n(), dfdu.n()    #numerical values of u, norm of grad f, dfdu
Out[1]: ((-0.447213595499958, 0.894427190999916), 1.64520687596796, -0.987124125580776)
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Fig. 1 Excerpt from a Jupyter notebook with an interactive 3D Geogebra simulation and a Sage code

3 Conclusion

Today's free interactive digital technologies (e.g. Google drive connected apps, Jupyter and Sage notebooks) provide a teacher of flipped math and physics learning strong opportunities for easy use of various formative assessment techniques like two-minute papers, self-assessment quizzes or digital annotations. Our results indicate that the proper integration of technology and assessment should lead not only to better-prepared, motivated students for in-class flipped learning activities but also to the development of the required conceptual understanding of key mathematical and physical concepts, self-monitoring and independence of students.

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