A Flow Measurement Instrument to Test the Students' Motivation in a Computer Science Course

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Abstract: Motivate students is a top research aspect for many research communities, schools, universities, and institutions. In this context, motivation has an important role in the leaning process and particularly in the students' success and the drop-out avoidance. This paper proposes a flow measurement instrument in order to test the students' motivation in a Computer Science course. The experimental study involved 33 students that answer a same questionnaire twice in a period of one week. The temporal stability, internal consistency and convergent validity of the first English version of the Flow in education scale (EduFlow) were examined. The results show that autotelic experience (well-being provided by the activity itself) is significantly positively correlated with academic achievement. This research work is dedicated to Education and Computer Science active communities and more specifically to directors of learning centres / pedagogy departments, and the service of information technology and communication for education (pedagogical engineers) who meet difficulties in evaluate students' motivation in a specific course.

1 INTRODUCTION

Nowadays, education is facing big changes based on concepts, theories, principles, and methods. Motivation is one of the most important factor that universities/institutions/teachers need to target in order to improve students' learning (Bhoje 2015). Palmer (2007) reviews the student motivation as an essential element that is necessary for the education quality.

According to Weiner (1992), motivation is the study of the determinants of thought and action—it addresses why behaviour is initiated, persists, and stops, as well as what choices are made. In general, most teachers are aware of the importance of keeping students motivated. According to Goleman (1996), "The extent to which emotional upsets can interfere with mental life is no news to teachers. Students who are anxious, angry, or depressed don't learn; people who are caught in these states do not take in information efficiently or deal with it well."

The efforts of teachers to motivate their students are not always successful, probably due to lack of training and deep understanding of all the issues involved in the class. The motivation behind this work is the teachers' difficulty to evaluate students' motivation in instructional situations.

Optimal experience (or Flow) "is a gratifying state of deep involvement and absorption that individuals report when facing a challenging activity and they perceive adequate abilities to cope with it" (EFRN 2014). The phenomenon is described by Mihaly Csikszentmihalyi in 1975 in order to explain why people perform activities for the activity itself, without extrinsic rewards. During flow state, people are deeply motivated to persist in their activities and to perform such activities again (Csikszentmihalyi, 1975). The experience is triggered by a balance between a person's skills in an activity and the challenges afforded by the lifelong learning environment. Flow has been shown to promote learning and personal development because deep and total concentration experiences are intrinsically rewarding, and they motivate students to repeat an activity at progressively higher levels of challenge (Csikszentmihalyi *et al.,* 2005). Potentially due to its positive consequences, flow research is further growing in the new millennium, and there is a plethora of empirical articles dedicated to this phenomenon.

In this paper, we are focusing on a flow measurement instrument in order to test the students' motivation in a Computer Science course. We choose the Research in Computing course in a Master

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programme entitled Cloud Computing because students in this field do not see the immediate benefit to have this course in their curriculum. Note that, in our context, 'instrument' is a novel psychometric scale to assess optimal experience in educational situations.

The paper is organized as follows. Section 2 presents some research work done in the area of flow and motivation to learn, focusing on flow in education. Section 3 describes our flow measurement instrument. Section 4 highlights our case study in an engineering school in Dublin. Section 5 presents the results of the case study. Section 6 summarizes the conclusion of this paper and presents its perspectives.

2 RELATED WORK

2.1 Flow and Motivation to Learn

As Csikszentmihalyi and LeFevre (1989) noted, "when both challenges and skill are high, the person is not only enjoying the moment, but is also stretching his or her capabilities with the likelihood of learning new skills and of increasing self-esteem and personal complexity". In this manner, the concept of flow is inherently relevant to learning and particularly important within educational settings.

According to (Culbertson *et al.*, 2015), research findings regarding flow within learning contexts have demonstrated that flow is associated with heightened creativity, persistence in studies (Nakamura 1988), and overall learning and academic performance (Csikszentmihalyi *et al.*, 1993). In addition, there is evidence that flow is related to teaching effectiveness and that flow within the classroom can crossover from one individual to others (e.g., from teacher to students);.

Optimal motivation and learning occur when perceived challenge and perceived skill are balanced and high. An imbalance between perceived challenge and skill can lead to decreased motivation, such as boredom when skills exceed challenge, or anxiety when challenge is higher than skill (Csikszentmihalyi 2014). Optimal motivation promote the most positive psychological / developmental / behavioural outcomes and psychological well-being (Deci and Ryan, 2002).

High perceived skill is especially advantageous when perceived difficulty is high. Learners who perceive that their skills are high and matched with the level of challenge report higher enjoyment, interest, and positive affect (Shernoff *et al.*, 2003), and are more likely to persist or wish to continue with a task (Csikszentmihalyi *et al.*, 1993).

The main topic of flow in education was the link of flow with motivational indicators. Beside motivation, some studies related flow to (a) engagement (Mesurado *et al.*, 2016); (b) goal orientation (Oertig *et al.*, 2014), (c) achievement motives (Engeser and Rheinberg, 2008), (d) interest (Bachen *et al.*, 2016). This is not surprising because many authors consider flow experience as a state of the optimal motivation (Deci and Ryan, 2002; Heutte 2017).

The topic of flow in education has often been studied in combination with other theories. Many previous studies have examined the connection between flow and intrinsic motivation (Keller *et al.*, 2011). Intrinsic motivation involves doing a behaviour because the activity itself is interesting and spontaneously satisfying (Deci and Ryan, 2002). However, some authors introduce confusion by considering flow as intrinsic motivation. Indeed, it is quite possible to have an optimal experience during an activity that has not been chosen for intrinsic reasons (which is not a free choice). This is often the case like the first time a student performs a task to respond to a teacher's request without any intrinsic motivation. It is thus possible to see that sometimes it can be the challenge (complexity or task requirements) imposed by a prescribed task that goes in a completely unexpected way (for the student) to induce the state of flow, as if the flow literally fell on him without his expectation. In this case, it is during the activity that the student will find himself or herself gradually absorbed by the task and it is this absorption, combined with the fact of realizing that he or she is progressing (sometimes beyond what he or she thought he or she was capable of), that will bring pleasure to the work. Of course, it is this phenomenon that may induce the desire to re-engage in the task, this time for intrinsic reasons. Therefore, it would be more accurate to say that intrinsic motivation can be a consequence of flow (because the opposite is not always true). Thus, even if obviously all forms of autonomous motivation can promote flow, the fact remains that the confusion between intrinsic motivation and flow is indeed a conceptual error (Heutte 2017).

Other studies on motivation and flow are more linked to self-efficacy (Bandura 1997). Results highlight that self-efficacy is linked to flow frequency, higher levels of challenge, and skills. These results also show that self-efficacy predicts flow over time (Heutte *et al*, 2016). High efficacy beliefs levels have a positive impact on flow

Table 1: Some instruments examples used to study flow in an educational context.

Scales	Authors	Items nb	Dim nb
Flow Questionnaire* (Flow Q)	Csikszentmihalyi and Csikszentmihalyi (1988)	3	n.a.
Flow in Human-Computer Interaction	Ghani and Deshpande (1994)	15	4
Flow in Online Environments	Novak *et al* (2000)	66	13
Flow State Scale-2 (FSS-2)	Jackson and Eklund (2002)	36	9
Flow-Kurzskala (FKS)	Rheinberg *et al* (2003)	10	1
EGameFlow	Fu *et al* (2009)	42	8
Échelle de mesure du flow en éducation (EduFlow)	Heutte *et al* (2014)	12	4
Échelle de mesure du flow en éducation-2 (EduFlow-2)	Heutte *et al* (2016)	12	4

Note. * only for qualitative study

experiences in academic settings (Heutte *et al*., 2016; Salanova *et al.*, 2006). Various aspects of Bandura's (1986) self-regulation learning model were shown to exert a significant and positive effect on flow state (Chen and Sun, 2016). Higher congruence between one's implicit motives and self-attributed motives is associated with better self-regulation, goal attainment, and flow (Rheinberg and Engeser, 2012). Some studies highlight collective (or social) motivational conditions of flow: collective efficacy beliefs predict collective flow over time (Salanova *et al.*, 2014).

In any case, most studies show that the relation between flow and learning is complex because the learning process is not simple. Flow predicts motivational outcomes (intrinsic motivation, interest, self-efficacy, self-regulation, persistence, etc.), but not always task performance (Durik and Matarazzo, 2009).

2.2 EduFlow

Various instruments have long been used to study flow in educational contexts (Table 1). However, according to Csikszentmihalyi, before the development of the Flow in education model (EduFlow) (Heutte *et al.*, 2014), there was no short multidimensional scale designed and dedicated specifically for education (some generic scales were applied in education without being initially designed for this domain). "The understanding of flow within educational settings, however, is limited by the methodological approaches to date. For example, most research on the correlates of flow has been cross-sectional and therefore incapable of establishing the causal nature of the relationships between the potential antecedents and consequences of flow. In addition, cross-sectional studies must rely on measures assessing recalled flow as opposed to direct measures of flow at the times of the activities" (Culbertson *et al.*, 2015). Note that in table 1, nb refers to number and dim to dimension.

In order to carry out a convergent validity test with this first English version of the Flow in Education Scale (EduFlow), we have selected two standardized measurement instruments whose main characteristics are: (1) short scales and (2) scales very regularly used in international scientific work. In our context, we use the Flow Short Scale (Rheinberg *et al*., 2003) and the General Self-Efficacy Scale (Schwarzer, and Jerusalem, 1995).

3 OUR FLOW MEASUREMENT INSTRUMENT

3.1 An Overview of Our Approach

Figure 1 shows an overview of our design and evaluation approaches. Three actors are involved in the design of our flow measurement instrument: the psychologist researcher who designs the instrument, the learning psychologist who uses the proposed instrument in order to contextualize it, and the teacher who validates the contextualized instrument based on the course and the vocabulary used in the class. Regarding the use of the instrument, the learning psychologist puts the contextualized instrument in the dedicated learning environment (for example lime survey) and the teacher runs it in the class where students answer the questions of the contextualized instrument. Then, the learning psychologist anonymizes and analyzes student's answers via a statistical analysis software like SPSS statistic, R, etc.

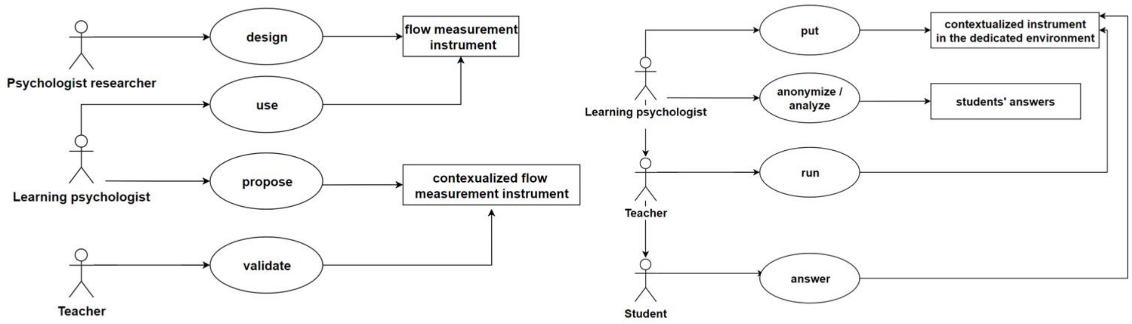

Figure 1: An overview of our approach from the design side (on the left) and the evaluation/use side (on the right).

3.2 Instruments

The Flow in education scale version 2 (EduFlow-2) is a twelve-item scale and it differentiates 4 flow dimensions (there are three items per dimension):

- FlowD1-Cognitive Control: a strong feeling of control, specifically over one's actions, characterized by a feeling of ability to deal with the situation and a feeling that the student knows how to deal with whatever comes next ("I feel completely in control of my actions");
- FlowD2-Immersion and Time Transformation: alteration in the perception of time, sometimes leading to a lengthened duration of immersion in the task ("I am wholly absorbed in what I am doing");
- FlowD3-Loss of Self-Consciousness: lack of self-concern related to an increase in importance of the psycho-social dimension of learning ("I don't care about what others may think of me");
- FlowD4-Autotelic Experience: well-being provided by the activity itself enhances persistence and the desire to engage in the activity again ("This activity brings me a sense of well-being").

When tested *via* Confirmatory Factor Analysis, the EduFlow-2 showed significant improvement in all fit indices (Heutte *et al.*, 2016). We have consequently gathered FlowD1, FlowD2 and FlowD3, namely Cognitive Control, Immersion and Time Transformation, and Loss of Self-Consciousness, under Cognitive Absorption (Figure 2).

The EduFlow has three main advantages:

- It suits flow measurement in various educational contexts;
- It is a short instrument (reducing respondent burden);
- It highlights the difference between four dimensions of flow that are related to a cognitive process.

This scale was used to measure flow after classrooms activities (7-point scale).

Flow was complementary measured with the Flow Short Scale (Rheinberg *et al.*, 2003). This scale measures all components of flow experience with ten items ("My mind is completely clear") and was used to measure flow after classrooms activities (7-point scale). The first flow model (Csikszentmihalyi 1975) proposes that flow occurs when the actor perceives a balance between the challenge of the activity and his or her own skill. Due to theoretically inconsistent results, this model was reformulated: the revised model proposes that flow is experienced only when challenge and skill are both high (Csikszentmihalyi and Csikszentmihalyi, 1988), that's why according to (Engeser and Rheinberg, 2008), we add three additional items to measure the perceived importance (''Something important to me is at stake here'', ''I won't make any mistakes here'', and ''I am worried about failing''). The experienced difficulty of the task, perceived skill and perceived balance were measured on a 7-point scale.

Many studies on motivation and flow are linked to Social Cognitive Theory (Bandura, 1986). Results highlighting that self-efficacy is linked to flow frequency and have a positive impact on optimal experiences in academic settings (Heutte *et al.*, 2016; Salanova *et al.*, 2006). The German version of General Self-Efficacy Scale (GSES) developed in 1979 by Jerusalem and Schwarzer and later revised (Schwarzer, and Jerusalem, 1995), and adapted to 26 other languages by various co-authors. GSES is a ten items scale; ("It is easy for me to stick to my aims and accomplish my goals") created to assess a general sense of perceived self-efficacy with the aim in mind to predict coping with daily hassles as well as adaptation after experiencing all kinds of stressful life events. This scale was used to measure flow after classrooms activities (7-point scale).

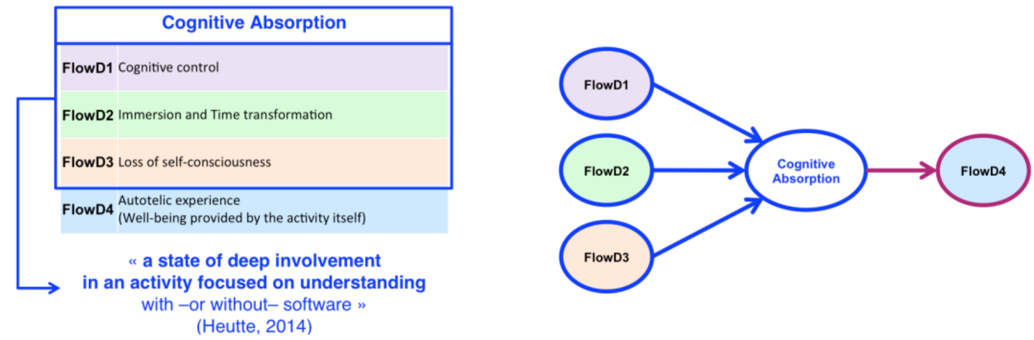

Figure 2: Cognitive Absorption Modelling (Heutte 2017).

4 CASE STUDY

The goal of this research study was to investigate learner motivation in a Computer Science course. This section presents the evaluation methodology applied and case study set-up.

The evaluation included a group of master students who were taught the Research in Computing course. In this course, learners acquire the fundamental computing research skills in Cloud computing of an MSc programme in order to set up the foundations of a research project via a major literature review and a project plan. In the course, there is an assessment about writing a research paper (~20 pages). This paper must be submitted at the end of the course.

The evaluation took place in class, during the normal hours of study. A total of 33 students (21.2% woman and 78.8% man) of average age 25.7 years (Standard Deviation = 2.3 years) with a range from 21 to 30, from an engineering school located in Dublin, Ireland took part in the case study. Team members from the school and the Université de Lille (in France) have prepared and helped perform the tests. The students volunteered to participate in a study that required them to complete two surveys for an average test–retest interval of about seven days. Once the assessment is corrected, we compare the grades with the motivation indicators.

The evaluation meets all Ethics requirements. Prior to running the case study, all required forms were provided to the students including informed consent form, informed assent form, plain language statement and data management plan. These documents include a detailed description of the testing scenario, as well as information on study purpose, data processing and analysis, participant identity protection, etc.

The evaluation process is illustrated in Figure 3 that presents in details the steps followed by the researchers. It can be seen that prior to beginning the evaluation, the consent forms signed by students were collected. Then the students were introduced to the research case study and asked to review and sign the assent form. The students had roughly 20 minutes to answer the questionnaire (see appendix).

The learner motivation questionnaire assessing student motivation was collected. After 1 week of this evaluation, the students were asked to answer the same questionnaire in order to verify the temporal stability and internal consistency of our flow measurement instrument. This instrument is the first English version of the Flow in education scale.

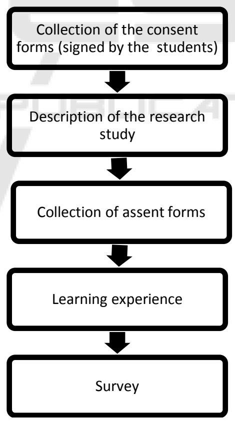

Figure 3: Evaluation process.

5 CASE STUDY RESULTS ANALYSIS

The analyses were carried out in two stages: (1) verify certain psychometric qualities of our novel instrument EduFlow, and (2) study links between academic success and different psychological determinants of motivation highlighted by this new measurement instrument. Note that all statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 23.

5.1 Quality of the Eduflow

Table 3 presents the test and retest means, standard deviations, and test–retest stability coefficients for the 12 items of EduFlow. The results of this first analysis highlight that there is no significant difference in the answers at one week interval for each of the 12 items. This confirms the temporal stability of the EduFlow.

Cronbach's alpha (Cronbach 1951) is so far the most frequently reported reliability coefficient. Table 1 presents the internal consistency coefficient alphas for each dimension of the EduFlow. According to (Hinton *et al*., 2014), coefficient alphas .50 to .70 shows moderate reliability, .70 to .90 shows high reliability, .90 and above shows excellent reliability. According to Moss and colleagues (1998, cited by Hair *et al.*, 2006), the .60 level of Cronbach´s alpha is acceptable.

The coefficient alphas (Table 1) shows excellent reliability for FlowD3-Loss of Self-Consciousness (.93), high reliability for FlowD1-Cognitive Control (.84) and FlowD4-Autotelic Experience (.83), moderate reliability for FlowD2-Immersion and Time Transformation (.60).

Although the coefficient for FlowD2 is a little bit low, the analyses show that the reliability of the scale is acceptable. This confirms the internal consistency of each dimension of the EduFlow.

Bartlett's test of sphericity and the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy (Kaiser 1974) were used to evaluate the strength of the linear association between the items in the inter-item correlation matrix (Table 2). Bartlett's Test was significant (Chi-Square = 380.55, $p < .000$) and KMO value was .76, which is good (if >.70). The number of students in the case study was too small to conduct an exploratory factor analysis.

The convergent validity test (Table 3) highlights that all dimensions of EduFlow are significantly positively highly correlated (r=.56 to r=.88, $p < .01$) with Flow Short Scale (Rheinberg *et al*., 2003) and the General Self-Efficacy Scale (Schwarzer and Jerusalem, 1995). These results are fully in line with expectations. All these analyses confirm the good quality of the first English version of the EduFlow.

5.2 Results Focused on Motivation

First of all, we can see in table 4 that all mean score of motivation indicators (evaluated with 7-point Likert scale) are particularly high overall, both for all dimensions of the EduFlow (5.03 to 5.76), the Flow Short Scale (4.93) and the General Self-Efficacy Scale (5.56). We also notice that in all selected indicators, the one relating to difficulty has the lowest score (4.24).

Contrary to expectations, the results (Table 5) show that there is no significant link between the students' self-efficacy and their academic success (final grade obtained at the end of the course). Among all the flow indicators, there is only FlowD4-Autotelic Experience that is significantly related to academic success ($r = .38$, $p < .05$).

Some unexpected results, particularly regarding flow, may be due to the fact that students did not feel they were having a difficult experience. Indeed, in free fields of expression, many students emphasized the quality of the teacher's pedagogical support, particularly the time spent even outside the classroom to ensure that they had understood the requirements of the prescribed tasks (*Prof. Nour El Mawas helped us a lot. Prof. made us understand things in a very simple format by giving multiple example. Prof. used to repeat until we understand the concept clearly. I thoroughly enjoyed the lecture given by Prof. Nour El Mawas. I truly appreciate the way you had cleared*

Table 1: Reliability Statistics (Cronbach's Alpha Based on Standardized Items).

	Cronbach's Alpha	N of Items
FlowD1	.835	3
FlowD2	.602	3
FlowD3	.926	3
FlowD4	.831	3

Table 2: KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.764
Bartlett's Test of Sphericity	Approx. Chi-Square	380.554
	df	66
	Sig.	.000

Table 3: Paired Samples T-test Output.

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
					Inf.	Sup.			
Pair 1	FlowD1a (t1 *vs* t2)	-.273	1.153	.201	-.682	.136	-1.359	32	.184
Pair 2	FlowD2a (t1 *vs* t2)	-.030	1.357	.236	-.512	.451	-.128	32	.899
Pair 3	FlowD3a (t1 *vs* t2)	.129	2.109	.379	-.645	.903	.341	30	.736
Pair 4	FlowD4a (t1 *vs* t2)	-.061	1.638	.285	-.641	.520	-.213	32	.833
Pair 5	FlowD1b (t1 *vs* t2)	.030	1.649	.287	-.554	.615	.106	32	.917
Pair 6	FlowD2b (t1 *vs* t2)	.091	1.646	.287	-.493	.675	.317	32	.753
Pair 7	FlowD3b (t1 *vs* t2)	.188	1.635	.289	-.402	.777	.649	31	.521
Pair 8	FlowD4b (t1 *vs* t2)	-.485	1,889	.329	-1.155	.185	-1.474	32	.150
Pair 9	FlowD1c (t1 *vs* t2)	-.091	1.721	.300	-.701	.519	-.304	32	.763
Pair 10	FlowD2c (t1 *vs* t2)	-.152	1.839	.320	-.804	.501	-.473	32	.639
Pair 11	FlowD3c (t1 *vs* t2)	-.030	2.468	.430	-.906	.845	-.071	32	.944
Pair 12	FlowD4c (t1 *vs* t2)	-.269	1.845	.362	-1.015	.476	-.744	25	.464

Note: t1: test ; t2: retest (at one week interval); FlowD1, FlowD2, FlowD3 and FlowD4 are dimensions of EduFlow Scale (Heutte *et.al.*, 2016), for more information about all items please see appendix.

Table 4: Descriptive Statistics.

Motivation (7-point Likert scale)	Mean	*S.D.*	N
Cognitive Control (FlowD1)	5.76	1.35	33
Immersion and Time Transformation (FlowD2)	5.03	1.12	33
Loss of Self-Consciousness (FlowD3)	5.45	1.81	33
Autotelic experience (FlowD4)	5.12	1.60	33
Flow Short Scale (FSS)	4.93	1.15	33
Perceived importance (FSS-Imp)	4.48	1.86	33
Experienced difficulty (FSS-Diffic)	4.24	2.05	33
Perceived skill (FSS-Skill)	5.45	1.54	33
Perceived challenge-skill balance (FSS-Balance)	4.90	1.51	31
General Self-Efficacy Scale (GSES)	5.56	1.19	33

Grade (0 à 100)	Mean	*S.D.*	N
Grade	72.27	13.87	33

Note: FlowD1, FlowD2, FlowD3 and FlowD4 are dimensions of EduFlow scale (Heutte *et.al.*, 2016); FSS-Imp, FSS-Diffic, FSS-Skill and FSS-Balance are additional factors include in Flow Short Scale (FSS, Rheinberg, *et al.*, 2003), GSES (Schwarzer, and Jerusalem, 1995).

Table 5: Correlation among motivational indicators and academic performance (grade).

		1	2	3	4	5	6	7	8	9	10	11	12
1	EduFlow												
2	Cognitive Abs.	.958**											
3	FlowD1	.899**	.878**										
4	FlowD2	.810**	.845**	.712**									
5	FlowD3	.808**	.889**	.628**	.596**								
6	FlowD4	.743**	.520**	.629**	.440*	.333							
7	FSS	.832**	.820**	.797**	.700**	.668**	.564**						
8	FSS-Imp	.452**	.433*	.332	.385*	.409*	.334	.331					
9	FSS-Diffic	.387*	.440*	.312	.437*	.406*	.127	.191	.129				
10	FSS-Skill	.792**	.814**	.679**	.774**	.697**	.460**	.782**	.391*	.192			
11	FSS-Balance	.501**	.512**	.477**	.585**	.340	.294	.460**	.253	.570**	.434*		
12	GSES	.875**	.795**	.816**	.697**	.603**	.752**	.781**	.442*	.270	.703**	.535**	
13	Grade	.304	.226	.290	.028	.233	.380*	.259	.076	-.064	.019	-.098	.240

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).
Note: FlowD1, FlowD2, FlowD3 and FlowD4 are dimensions of EduFlow Scale (Heutte *et.al.*, 2016); Cognitive absorption = FlowD1+FlowD2+FlowD3; FSS-Imp, FSS-Diffic, FSS-Skill and FSS-Balance are additional factors include in Flow Short Scale (FSS, Rheinberg, *et al.*, 2003), GSES: General Self-Efficacy Scale (Schwarzer and Jerusalem, 1995).

everybody's doubts and was amazed when I found out that you have made a lot of contributions in the field of RIC. Will be happy to get a professor like Nour El Mawas in future. We are really glad to have prof. Nour for our RIC subject. I haven't met professor like Nour in my life ever. I am sure that the notes given by you will definitely be helpful to us during our project and I am sure that I am going to score well in RIC. Thanks Professor.) Note that RIC refers to Research in Computing.

To summarize the above analysis, we can deduce that:

(1) All our tests confirm the good quality of the first English version of the EduFlow: temporal stability, internal consistency, and convergent validity.

(2) The relation between flow and learning is complex because the learning process is not simple. Flow predicts students' motivation, particularly self-efficacy, but not always academic performance.

(3) It is better to use a multidimensional measurement instrument, as EduFlow, to study students' motivation in learning situations, because it allows to highlight some components of the optimal experience, which is not possible with a unidimensional scale.

6 CONCLUSIONS

In this research paper, we investigate the motivation in a Computer Science course. A flow measurement instrument was designed and tested with students from a Dublin-based engineering school. This instrument is the first English instrument to assess flow in education. The case study proves that the students' academic achievement is significantly correlated with the autotelic experience which presents the well-being provided by the activity itself.

Future work will aim to expand the research study on our flow measurement tool by increasing the number of participants (learners) in order to follow researchers' recommendations on exploratory and confirmatory analyses (Hair *et al.*, 2006). Further research will include a scale to assess student's feelings of relatedness (Deci and Ryan, 2014; Richer and Vallerand, 1998). The motivation and the social belonging impact on the learning will also be evaluated.

We also want to increase students' motivation by promoting an optimal learning environment. In fact, researchers have shown the benefits of integrating interpersonal relations on the motivation (Deci and Ryan, 2002, 2014, Heutte 2017).

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APPENDIX: EduFlow

Read each sentence carefully and answer, on the scale opposite, by checking a number that best corresponds to what you think.

In general as part of activities related to the *Research in Computing* course...

Code		1 Not at all	2	3	4 Partly	5	6	7 Very much	I don't know
FlowD1a	I trust my ability to meet the high demands of the situation.								
FlowD2a	I am wholly absorbed in what I am doing								
FlowD3a	I don't care about what others may think of me.								
FlowD4a	I have the feeling I am living a very exciting experience.								
FlowD1b	I feel completely in control of my actions								
FlowD2b	I am deeply focused on what I am doing.								
FlowD3b	I am not concerned about the judgement of others.								
FlowD4b	This activity brings me a sense of well-being.								
FlowD1c	At each step, I know exactly what I have to do								
FlowD2c	I am losing track of time.								
FlowD3c	I am not worried about what others might think of me.								
FlowD4c	When I talk about this activity, I feel such a deep emotion that I want to share it.								

FlowD1: Cognitive control
FlowD2: Immersion and Time transformation
FlowD3: Loss of self-consciousness
FlowD4: Autotelic experience (well-being rooted in the activity itself)

Note : FlowD1+FlowD2+FlowD3 = Cognitive absorption

Note that the elements written in red were only visible for the teacher and the learning psychologist.

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