



FIG.3. Students' responses with a mental state diagram. Results of Spring 2012 and 2013.

This representation allows us to have a rough qualitative interpretation of students' responses these two questions through the lens of the flow theory. We can represent students' responses on this chart "difficulty" vs. "fun" with bubble sizes proportional to the number of students. The position of each bubble on this graph corresponds to the mental state of the student as shown in Figure 3. The results show that in year 2012 most of the students were in states "worry", "anxiety" and "arousal". In year 2013 we can see that most of the students were in states "arousal", "flow", and "control" with few students in "relaxation" state.

V. IMPLICATIONS

Based on our findings we can formulate suggestions

for those who want to implement the labs where students design their own experiments:

- The labs' objectives should be very clear to students so they know what to do;
- Tasks should be attainable to students with minimal help from an instructor;
- Tasks should have a clear outcome indicating a success for a clear feedback;
- Available equipment should give a large range of possible ways to solve a problem to increase perceived challenges;
- Exercises can be added to increase specific skills when students are aware of their lack of the skills; in Ref. 11 we found that student need about 5-8 weeks to develop different abilities, thus that the difficulty of the tasks should increase during the semester.

[1] E. Etkina, Am. J. Phys., **83**, 669 (2015)
 [2] E. Etkina and M. Ruibal-Villasenor, AIP Conf. Proc., **883**, 105-108 (2007).
 [3] M. J. Volkmann, S. K. Abell, and M. Zgagacz, Science Education, **89**, 847, (2005).
 [4] M. Csikszentmihalyi, *Flow: The Psychology of Optimal Experience*, (Harper and Row, New York, NY, 1990).
 [5] J. Nakamura, J. and M. Csikszentmihalyi, in *Handbook of positive psychology*, edited by C. R. Snyder and S. J. Lopez, (Oxford University Press, Oxford, UK, 2002), pp. 89-105.
 [6] F. Massimini and M. Carli in *Optimal Experience: Psychological Studies of Flow in Consciousness*, edited by M. Csikszentmihalyi,

and I. Csikszentmihalyi (Cambridge University Press, 1988), pp. 266-287.
 [7] G. B. Moneta, in *Advances in Flow Research*, edited by Stefan Engeser (New York, NY: Springer, 2012), pp. 23-50.
 [8] E. Etkina, S. Murthy, and X. Zou, Am. J. Phys. **74**, 979 (2006).
 [9] A. Karelina, AAPT conference, Orlando, FL, 2014.
 [10] The texts of the labs can be found on site <https://sites.google.com/site/scientificabilities/ISLE-labs>; "Calculus based", Semester 2, Mechanics
 [11] A. Karelina and E. Etkina, Phys. Rev. ST Phys. Educ. Res., **3**, 020106 (2007).