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The Hydrodynamic Performance Examination of a New Floating Breakwater Configuration

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Abstract— *It is critical to protect coastal and offshore structures. Most current studies and scientific investigations are centered on how to protect seashore with an efficient and cost-effective system. This study involved the testing of a new floating breakwater configuration (FB). A series of experiments were carried out in the lab of The Higher Institute of Engineering (El-shorouk City) on the new model and the traditional vertical plane FB without a curved face to compare their behaviours and performance in wave attenuation. The incident, reflected, and transmitted wave heights were measured, and the coefficients of reflection, transmission, and energy dissipation were calculated using these measurements. In terms of hydrodynamic performance, the curved-face floating breakwater outperformed the traditional vertical floating breakwater, according to the study's highlights. The curved face model significantly reduced wave transmission values when compared to the traditional vertical configuration. The greater the concavity of the curve, the better the model handles waves, especially when the wave steepness is low.*

Keywords— ***Curved face floating breakwater, Reflection Coefficient, Transmission coefficient, Energy dissipation coefficient, shore protection.***

I. INTRODUCTION

The parts of land that face the seas, oceans, marines, and ports are known as coastlines. Breakwaters are wave attenuators, which are used to dissipate wave energy and protect coastlines from wave attacks. Breakwaters are divided into two types: conventional and non-conventional. The growth of offshore and maritime activities increases the demand for larger ports, making conventional bottom breakwater construction difficult. Floating breakwaters have been widely used in the protection of seashores, coastlines, ports, and marines over the last few decades. Indeed, 90% of wave energy is distributed along a depth three times the wave height below the water's surface.

Various researchers and scientists worked on this issue from (Fang He et al., 2012) to (S Rahman et al., 2022). [1] Fang He et al. (2012) installed pneumatic chambers with the original rectangular floating breakwater; the increased mass and inertia of the model has a significant effect on wave attenuation. Furthermore, the energy is dissipated more effectively in the front chambers than in the back chambers. [2] Chun-Yan Ji et al. (2016) investigated the hydrodynamic performance of a new floating breakwater configuration. The effect of beam and oblique waves on a ten-cylinder floating breakwater with ten mesh cages and eighteen connectors was investigated. Overall, the results demonstrated the impact of this configuration on energy dissipation and wave attenuation. [3] Chun-Yan et al. (2017) studied the effect of wave attacks on a new structure, A Cylindrical Dual Pontoon-Net floating breakwater (CDPNFB) attached to one or more rows of plane net experimental model. This study discovered that increasing net porosity lowers the reflection coefficient and vice versa for the transmission coefficient. Furthermore, the more cylinders used, the greater the wave blocking achieved by the model. [4] Chun-Yan Ji et al. (2019) investigated the hydrodynamic performance of a double-row rectangular floating breakwater with porous plates through a series of experiments. The experiments were carried out in a wave flume measuring 40m*0.8m*1.4m. Overall, the results showed that porous plates with small motion responses and mooring forces have a significant effect on wave attenuation.

[5] Chun-Yan Ji et al. (2015) compared a new type of floating breakwater with double pontoons and a box type, and found that the new configuration, a cylindrical floating breakwater with a flexible mesh cage, outperformed the other two types in long and high waves. [6] Chun-Yan Ji et al. (2016) conducted an experimental study of four types of floating breakwaters; the results showed that the mesh cage model was more effective than the other types. [7] Zhiwen Yang et al. (2018) investigated the effectiveness of a new floating breakwater against wave attacks. This structure is made up of a water ballast double floating box with a vertical plate. The findings of this study revealed that water ballast attenuates the incident wave more than dry ballast, and that the height of the vertical plate is effective in reducing wave transmission. [8] Chun-Yan Ji et al. (2019) conducted a series of experiments to compare single and double-row floating breakwaters. In terms of wave attenuation, the double-row performed better than the single-row. [9] S Rahman et al. (2020) theoretically and experimentally compared a modified pontoon type with a pi-type breakwater. The study's findings revealed that the developed pontoon type model has less transmission coefficient than pi-type model also the peak value of the heave motion is smaller than that of the pi-type.

The curved face floating breakwater model was tested against regular wave attacks in this study to determine the effectiveness of the studied parameters on its efficiency. The goal of this paper is to try a new configuration based on previous studies. Experiments were performed on the models under the influence of various wave conditions in order to test the model's functionality before comparing the results.

II. EXPERIMENTAL WORK

This part shows the experimental equipment and model used in the experiments. Also, it states the steps that were taken to carry out the experimental work.

2.1 Experimental Equipment

A series of experiments were conducted in two-dimensional wave flume in the Hydraulics Laboratory of the Higher Institute of engineering (El Shorouk City). The flume is 12 m long, 0.5 m width and 0.6 m deep. The wave maker used is fly wheel type connected by steel rod to paddle. Two wave absorbers from sloped graded gravel were used in the tests to prevent standing wave from reflection. The absorbers were installed in the flume with suitable slopes ranges from (2:1 to 5:1) and its size ranging from (0.5 – 3 cm) in diameter. The mooring lines used during the experiments were steel wires covered by a plastic layer. Figures 1 and 2 show the wave flume and schematic diagram for the flume.

Fig. 1: The Wave Flume

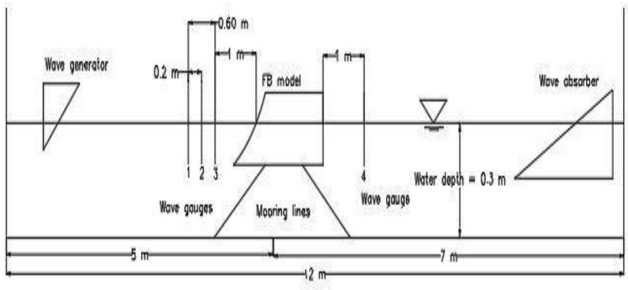

Fig. 2: Schematic Diagram of The Model in The Flume

An ultrasonic instrument (Wave Staff XB) used to determine the wave motion showing the wave heights versus time interval on a schematic diagram. The wave staff XB was installed in three positions to indicate incident, reflection, and transmission wave heights. The instrument was mounted on a small steel frame moves on the sides of the flume. The spacing between wave gauges applied were based on ([10] Mansard, and Funke, 1980) suggestions to calculate the relative distances between wave gauges. X_{12} = L/10, L/6 ≤ X_{13} ≤ L/3

Where L is the wavelength, X_{12} is the distance between the first two gauges positions and X_{13} is the distance between the first and third wave gauges in the line of wave propagation.

Each pattern was examined under the effect of five different wave heights, to complete this objective, about 135 runs were carried out and the wave heights were measured to determine the reflection, transmission, and energy dissipation coefficients, as the wavelength and wave heights are constant in all runs, then the incident wave heights were measured in the beginning of the experimental work. The wave gauges (1),(2) and (3) were used to determine the reflected wave height and wave gauge (4) was used to determine transmitted wave height.

2.2 Experimental Model

The supposed models were examined due to the proposed experimental program. The tested models were fixed to the base of the flume by steel wires with anchors fixed in the base. The parts of the model are two blocks (48 x 30 x 5 cm), one block (48 x 30 x 20 cm) and three curved parts with apex angles (30^o, 60^o, 90^o).

The experimental model used in this study is made of fiber and out covered by a timber layer, the pattern used in experimental work was to investigate the effect of each of the following parameters: The floating breakwater width (w), The floating breakwater draft (d) and the curvature of breakwater face (θ). The studied parameters and the model parts are shown in figure 3 and figure 4 respectively.

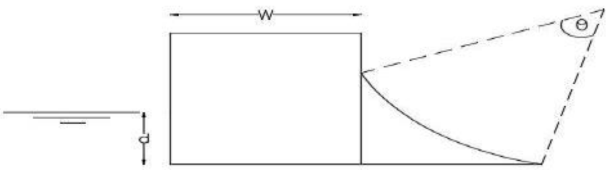

Fig. 3: The Studied Parameters

Fig. 4: Experimental Model Parts and its installation

2.3 Experimental Steps

A series of experiments were carried out in a 2D wave flume to study the effectiveness of the curved face floating breakwater. The new configuration was studied by testing various widths (20, 25 and 30 cm), different draft values (2, 10 and 20 cm) and three apex angles (30, 60 and 90 degrees). Each model was examined against five different wave heights (16, 11, 6.25, 4.5 and 2.5 cm) with constant wavelength approximately equals 248 cm and water depth equals 30 cm. The incident reflected and transmitted wave heights were calculated using the plot from the wave staff XB illustrated in figure 5. Also, the wave staff XB used in experiments is illustrated in figure 6. Both maximum and minimum heights were recognized from the wave staff plot, then the calculation of the wave heights was as follows:

Incident wave height $(H_I) = \frac{H_{max} + H_{min}}{2}$ (1)

Reflected wave height $(H_R) = \frac{H_{max} - H_{min}}{2}$ (2)

Transmitted wave height $(H_T) = H_{max} - H_{min}$ (3)

Reflection Coefficient $(C_r) = \frac{H_R}{H_I}$ (4)

Transmission Coefficient $(C_t) = \frac{H_T}{H_I}$ (5)

Energy Dissipation Coefficient $(C_d) = \sqrt{1 - C_t^{\,2} - C_r^{\,2}}$ (6)

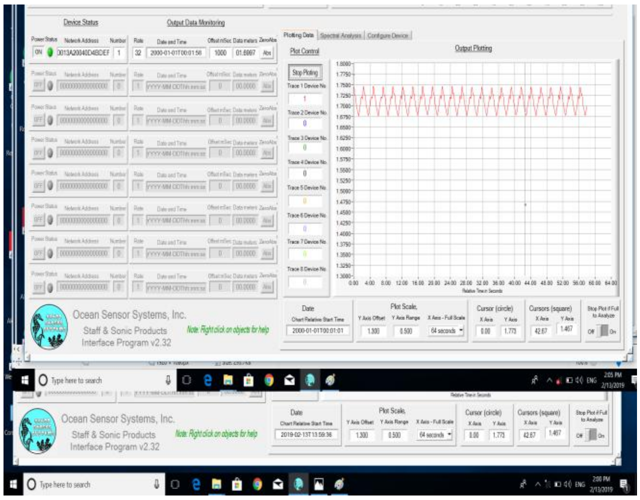

Fig. 5: The Wave Staff XB Plot

Fig. 6: The Wave Staff XB

2.4 Hydraulic Modeling

The water viscosity and surface tension are not the dominant factors that affect the phenomenon. While the gravity force and inertia are main parameters affecting the phenomenon. Thus, the Froude law is used in simulating the phenomenon.

$$F_N = \frac{V}{\sqrt{gL}} \tag{7}$$

F_N (model) = F_N (prototype)

$$\left(\frac{V}{\sqrt{gL}}\right)_m = \left(\frac{V}{\sqrt{gL}}\right)_p \tag{8}$$

$$L_r = \frac{L_m}{L_p} \tag{9}$$

$$V_r = \frac{V_m}{V_p} = \frac{\sqrt{L_m}}{\sqrt{L_p}} = \sqrt{L_r} \tag{10}$$

$$T_r = \frac{T_m}{T_p} = \frac{\frac{L_m}{v_m}}{\frac{L_p}{v_p}} = \frac{L_r}{v_r} \tag{11}$$

$$T_r = \frac{L_r}{\sqrt{L_r}} = \sqrt{L_r} \tag{12}$$

Considering Wave Characteristics, Wave Celerity (C):

$$C = \frac{L}{T} \tag{13}$$

$$C_r = \frac{C_m}{C_p} = \frac{L_r}{T_r} \tag{14}$$

$$C_r = \frac{L_r}{\sqrt{L_r}} = T_r \tag{15}$$

Depending on the dimensions of the flume and the wave conditions (length, height) that will be applied on the models. A ratio of 1:20 was selected for the construction of the curved face floating breakwater model.

III. EXPERIEMNTAL RESULTS

The hydrodynamic performance of the curved face floating breakwater models was investigated by measuring wave reflection and transmission heights then calculating reflection, transmission and energy dissipation coefficients. Finally, a comparison was held between the tested apex angles of curved faces used in the experiments.

3.1 Effect of Apex angle on reflection coefficient

The applied experiments showed the role of the curvature of the facing curve to wave attacks. The 30-, 60- and 90-degree curves were tested with different widths, drafts and five wave heights. The results proved that as the apex angle decreases which leads to the increment of curvature the reflection coefficient increases. this was highlighted as the 30-degree curve with 30 cm width, 20 cm draft gives the maximum values of reflection coefficients, on the other hand, the 90-degree curve when fitted with the same width and draft gives less values of reflection coefficients as shown in figure 7.

Figure 7 shows that the 30-degree curve recorded better results than the 60 degree and 90-degree curves, as it resists the wave motion more than the other two curves. These words could be more discussed with statistics that showed that the 30-degree curve reflected the incident wave with range from 88% to 97% for the five values of wave steepness. Thus, the 90-degree curve gave results from 84% to 92%. The 60-degree curve recorded values in between the 30 degree and 90-degree curve. The reflection coefficients produced from the tests of vertical face floating breakwater range from 82% to 90%. These results shows that the effectiveness of 30-degree curve in wave attenuation when compared with other curves and vertical face. also, it shows that the increment of the reflection coefficient with decreasing value of wave steepness attacking the curved face floating breakwater model. In addition to that, the curved face behavior is more efficient in low values of wave steepness than high values.

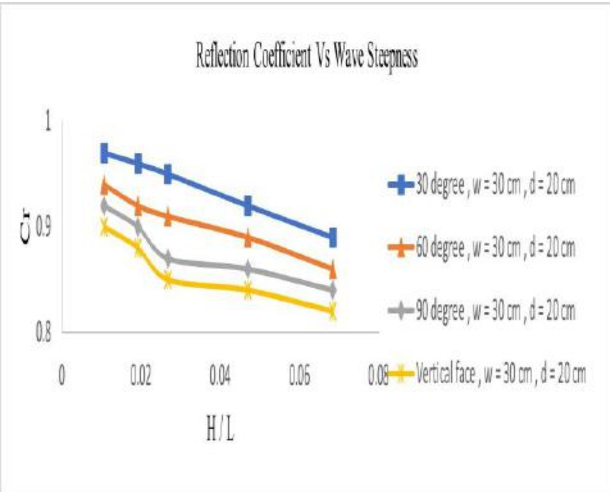

Fig. 7. Reflection Coefficient Vs Wave Steepness for Different Examined Curvatures & Width = 30 cm

3.2 Effect of Apex angle on transmission coefficient

The hydrodynamic performance of the floating breakwater is determined mainly by the transmission coefficient resulted from experiments carried out on the model. The highest values of transmission coefficients were resulted from the 90-degree curve, but less values were investigated from the tested 30-degree curve. The values of transmission coefficients recorded by the 30-degree curve illustrate the efficiency of this curvature in facing wave when comparing the experimental results of the three tested curves, the 30-degree curve showed the best performance by decreasing the transmitting wave from the coming incident wave, while the other two curves gave more values of transmission coefficients than the 30-degree curve as shown in figure 8.

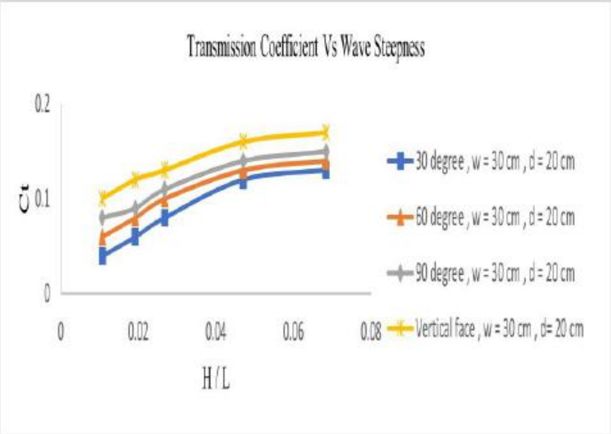

Fig. 8. Transmission Coefficient Vs Wave Steepness for Different Examined Curvatures & Width = 30 cm

3.3 Effect of Apex angle on Energy dissipation coefficient

The energy dissipation coefficient was calculated using the values of reflection and transmission coefficients. Figure 9 shows that by increasing the apex angle of curved surface, the energy dissipated from the incident wave increases. the vertical face floating breakwater recorded the highest energy dissipation coefficients values.

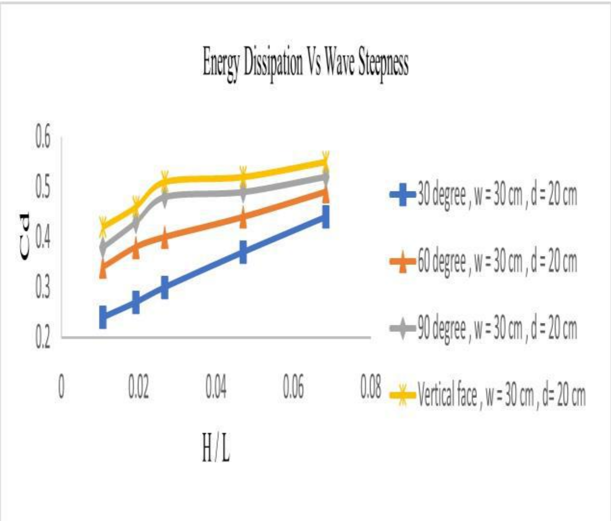

Fig. 9. Energy Dissipation Coefficient Vs Wave Steepness for Different Examined Curvatures & Width = 30 cm

3.4 Effect of width relative to wavelength on the hydrodynamic performance

The ratio of width relative to wavelength indicates the energy dissipated from the floating breakwater. the wavelength in the conducted experiments was 248 cm and the three widths used were 20, 25 and 30 cm. Figures 10, 11 and 12 showed the reflection, transmission and energy dissipation coefficients versus the width to wave length ratio (W/L). The coefficients shown in the figures are average values as for each width, the model was examined by five different wave heights and draft values. The increment of this ratio lowers the transmission coefficient for floating breakwaters and adjust the hydrodynamic performance against wave attacks.

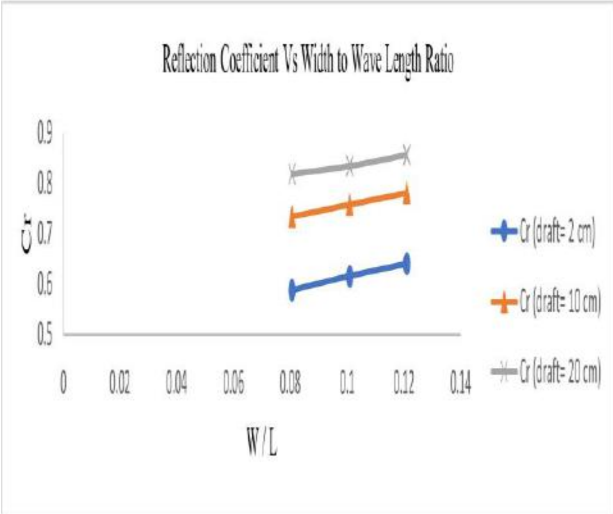

Fig. 10. Reflection Coefficient Vs Width to Wavelength ratio with different drafts

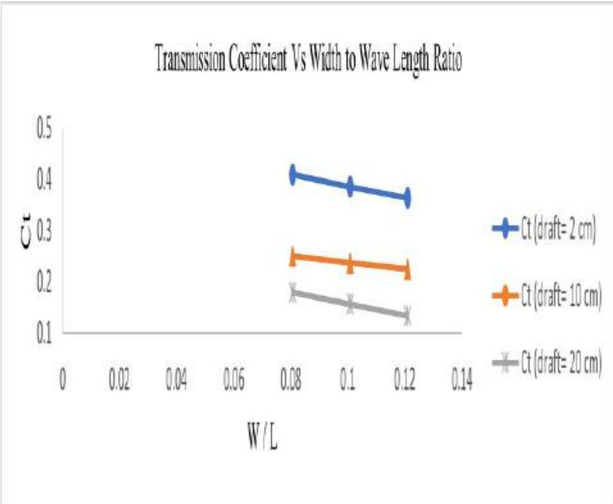

Fig. 11. Transmission Coefficient Vs Width to Wavelength ratio with different drafts

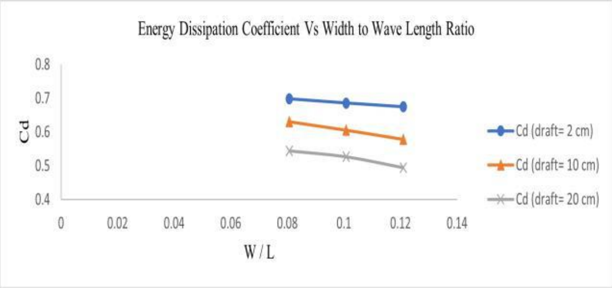

Fig. 12. Energy Dissipation Coefficient Vs Width to Wavelength ratio with different drafts

3.5 Effect of width and draft on curved face floating breakwater performance

The results showed that the best performance recorded for the examined model when the tested model was 30 cm width, 20 cm draft and 30-degree curvature, while the least hydrodynamic performance in wave attenuation and damping when the 20 cm width, 2 cm draft and 90 degree was used.

Figures 13 and 14 illustrated showed that the performance of the 30-degree curve increases with the increment of width and draft. The best performance was when the 30 cm width and 20 cm draft were used. On the other hand, the 20 cm width and 2 cm draft gave the weakest results in the tests.

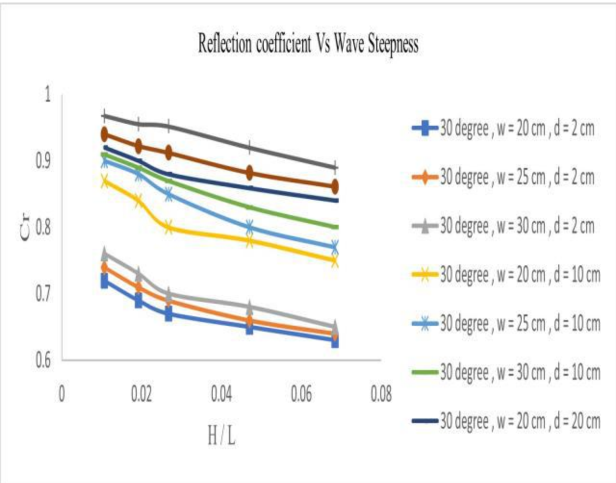

Fig. 13. Reflection Coefficient Vs Wave Steepness for 30-degree curvature with different widths and drafts

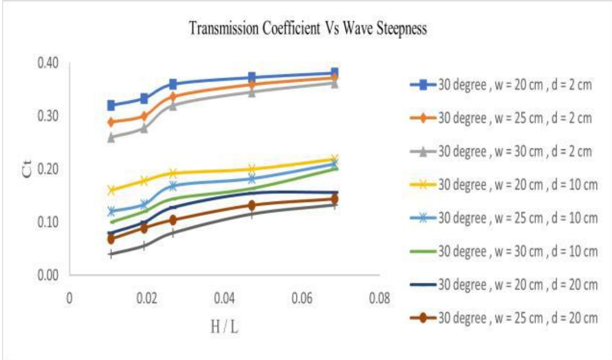

Fig. 14. Transmission Coefficient Vs Wave Steepness for 30-degree curvature with different widths and drafts

IV. ANALYSIS AND DISCUSSIONS

The experimental results demonstrate the effect of increasing the width and draught of the floating breakwater on the development of its performance. In addition to the effect of curvature on wave reflection and transmission by studying three different curvatures as previously discussed. When the results of the three curved surfaces were compared, it was discovered that the 30-degree curvature performed better in wave attenuation than the others. As a result, the curvature of the surface facing the wave attacks has a significant impact on the performance of the floating breakwater. The coefficients of reflection, transmission, and energy dissipation were measured for a variety of configurations with varying wave heights. These coefficients, particularly transmission, indicate the resistance of waves to the floating breakwater. The results of the examined models were compared, and graphical charts were created to determine the best coefficients. Furthermore, studying the results of this paper and comparing them to the performance of other floating breakwaters will result in useful data and increased knowledge in the field of floating breakwaters. Table 1 summarizes the experimental findings.

V. V. CONCLUSION

This study's findings concentrated on the effect of a curved face floating breakwater against regular wave attacks in a 2D wave flume. To investigate the hydrodynamic performance of a new configuration of floating breakwater model, experiments were carried out. According to the findings of this study, the greater the concavity of the curved face floating breakwater, the better the performance of the new type of floating breakwater when compared to the original vertical face floating breakwater. As is well known, the width and draft of floating breakwaters play an important role in increasing the reflection coefficient and decreasing the transmission coefficient. In this study, the

30 cm width and 20 cm draft produce the best results when compared to the other widths and drafts used. The reflection coefficient rises by around 25% and the transmission coefficient falls by 28% compared to the recorded values for 20 cm width and 2 cm draft, as shown in figures 7 and 8. The effectiveness of the curved face is directly proportional to the wave steepness decrement. The curved face floating breakwater is better than the vertical face floating breakwater in terms of hydrodynamic performance. Curved faces have a higher reflection coefficient than vertical faces. The average percentage increase in reflection coefficient as values change from low wave steepness to high wave steepness is around 7% for 30-degree curvature, 4% for 60-degree curvature, and 2% for 90-degree curvature. While the transmission coefficient decreases by 4.5%, 3%, and 2% for 30, 60, and 90-degree curvature, respectively as shown in table 1 for all other investigated configurations.

Based on previous research ([11] Koutandos et al., 2005; [12] Tolba et al., 1998) and various studies applied to floating breakwater (box type...)................etc., the studied new configuration is similar to the ordinary box type floating breakwater, i.e. it is a curved part attached to a box. As a result, the study's findings recommend designing and employing this new configuration when the water depth to wavelength ratio is 0.12, the floating breakwater depth to wave length ratio is 1, and the draught to water depth ratio is 0.67. These ratios are similar to those of the box type.

Table 1: Studied Parameters and Ranges of Coefficients

Studying Parameters			Ranges (%)		
Curvature	Width	Draft	C_r	C_t	C_d
30°	20 cm	2 cm	62.5 to 72	32 to 38.13	61.56 to 68.12
30°	25 cm	2 cm	64 to 74	28.8 to 37.19	60.78 to 67.18
30°	30 cm	2 cm	65 to 76	26 to 36.25	59.57 to 66.79
30°	20 cm	10 cm	75 to 90	16 to 21.88	40.55 to 62.42
30°	25 cm	10 cm	76.88 to 92	12 to 20.94	37.31 to 60.43
30°	30 cm	10 cm	77.81 to 96	6 to 20	27.35 to 59.54
30°	20 cm	20 cm	84.06 to 92	10 to 15.63	37.89 to 51.86
30°	25 cm	20 cm	86.13 to 94	6.8 to 14.38	33.43 to 48.74
30°	30 cm	20 cm	87.5 to 96.8	4 to 13.25	24.77 to 46.56
60°	20 cm	2 cm	58.75 to 66	33.2 to 39.38	22.71 to 24.99
60°	25 cm	2 cm	61.56 to 70	31.2 to 38.13	64.24 to 68.97
60°	30 cm	2 cm	63.75 to 74	28 to 37.19	61.16 to 67.48
60°	20 cm	10 cm	72.50 to 84	18 to 22.81	51.19 to 64.99
60°	25 cm	10 cm	74.38 to 88	15.2 to 21.88	45 to 63.17
60°	30 cm	10 cm	75.94 to 92	10 to 20.94	37.89 to 61.60
60°	20 cm	20 cm	82.5 to 88	12 to 16.56	45.96 to 54.03
60°	25 cm	20 cm	84.38 to 92	8.8 to 15.31	38.19 to 51.44
60°	30 cm	20 cm	85.94 to 94	6 to 14.06	33.59 to 49.16
90°	20 cm	2 cm	58.13 to 64	37.2 to 40.63	67.23 to 70.51

90°	25 cm	2 cm	59.06 to 68	34 to 39.38	64.96 to 70.44
90°	30 cm	2 cm	60.94 to 72	30 to 38.13	62.58 to 69.52
90°	20 cm	10 cm	70.63 to 80	22 to 23.75	55.82 to 66.70
90°	25 cm	10 cm	72.5 to 82	20 to 22.81	53.63 to 64.99
90°	30 cm	10 cm	74.38 to 88	18 to 21.88	43.95 to 63.17
90°	20 cm	20 cm	81.56 to 86.4	14 to 17.5	48.36 to 55.15
90°	25 cm	20 cm	82.5 to 88.8	11.2 to 15.94	44.60 to 54.22
90°	30 cm	20 cm	84.38 to 92	8 to 15	38.37 to 51.54
Vertical	20 cm	2 cm	55.94 to 62	39.2 to 42.81	67.97 to 70.98
Vertical	25 cm	2 cm	57.81 to 66	35.6 to 40.94	66.16 to 70.58
Vertical	30 cm	2 cm	58.75 to 69.2	32.8 to 39.69	64.31 to 70.52
Vertical	20 cm	10 cm	68.75 to 77.6	22.8 to 26.88	58.81 to 67.46
Vertical	25 cm	10 cm	70.88 to 79.6	22 to 24.88	56.39 to 66.01
Vertical	30 cm	10 cm	71.88 to 83.2	20.4 to 23.94	51.59 to 65.28
Vertical	20 cm	20 cm	79.69 to 84	16 to 20.13	51.85 to 56.96
Vertical	25 cm	20 cm	80.94 to 86	12.8 to 17.94	49.40 to 55.92
Vertical	30 cm	20 cm	81.88 to 90	9.2 to 16.88	42.61 to 54.88

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Measurement and Analysis of the Stability of Local Fiscal Revenue

Yu Fengze

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***Abstract*— *The stability of fiscal revenue, so called the fluctuation of fiscal revenue, refers to the fluctuation degree of local government's actual fiscal revenue deviating from the expected fiscal revenue. As the main way of funds for local governments to perform public service functions, fiscal revenue is an important starting point for local governments to regulate and participate in economic activities. The drastic fluctuation of fiscal revenue will interfere with the government's economic functions, reduce the quantity and quality of public services, and produce inefficient government activities. The economic and social activities carried out by governments at all levels in practice are numerous and complicated, which can be classified according to different purposes and perspectives. However, no matter which classification method is adopted, stable financial revenue is the core guarantee of government economic activities, which is in the position of "leading the development and affecting the whole body". Based on the combination variance method of white (1983), this paper constructs the stability index of local fiscal revenue, and measures the stability of fiscal revenue of all provinces in China, and interprets and analyzes the measurement results through the theoretical method of economics. It is found that there are significant regional differences in the fluctuation of local fiscal revenue in China. By comparing the changes of fiscal revenue fluctuation index in 2000, 2009 and 2018, the fluctuation index of fiscal revenue shows obvious regional differences. The fluctuation degree of the economically developed eastern coastal area is lower than that of the underdeveloped central and Western Region, and the southern region with lower economic activity is significantly lower than that of the north. On the other hand, the external shocks such as "replacing business tax with value-added tax" and financial crisis also have a positive impact on local tax fluctuations. Through the analysis of the experimental results, it is found that good economic foundation, capital accumulation, industrial structure and geographical location have a great impact on financial stability. Therefore, the government should pay attention to the gap between the stability of fiscal revenue in different regions, actively improve the economic foundation of the poor stability of the central and western regions, formulate differentiated economic and financial policies, vigorously develop the secondary and tertiary industries, and improve the stability of fiscal revenue to cope with regional economic risks and improve the administrative efficiency of the government.*

***Keywords*— financial revenue stability regional differences.**

I. INTRODUCTION

The stability of fiscal revenue, also known as fiscal revenue fluctuation, refers to the degree to which the actual fiscal revenue of local governments deviates from expected fiscal revenue. Since the reform and opening up, China has established the development goal of focusing on economic construction, the socialist market economy system has gradually been established and improved, and local governments, as an important carrier serving regional economic development, play an important role in macroeconomic regulation and control of the regional economic operation, economic policy formulation and implementation, and so on. Xi Jinping in the Central Political Bureau of the collective study has pointed out that the current relationship between the government and the market is the core issue of China's economic system reform, the use of dialectics and the two-point theory of scientific approach to the role of the market and the role of government. The "invisible hand" and the "visible hand" should be used to make the market play a decisive role in the allocation of resources and better play the role of the government of the two organic unity. Fiscal revenue plays an important role in regional economic development because it provides an important financial guarantee for local governments to carry out their economic functions. On the one hand, stable fiscal revenue is a necessary prerequisite for stable fiscal expenditures and determines the continuity and consistency of local governments' economic behavior; on the other hand, stable fiscal revenue is an important grasp for local governments to deal with regional debt risks and ensure government solvency. As a result, the stability of fiscal revenue and its impact on the economic behavior of local governments is receiving increasing attention.

Based on White's (1983) combined variance method, this paper constructs local revenue stability indicators and measures the fiscal revenue stability of each province, municipality, and autonomous region in China, and then explains and analyzes the measurement results using theoretical economic methods to provide policy recommendations for the next step of government to improve fiscal revenue stability.

The remaining section is organized as follows: the second part is a literature review section, which focuses on reviewing relevant research results on fiscal revenue stability at home and abroad, identifying flaws in existing research methods in the literature, particularly in research related to the measurement of fiscal revenue stability, and determining the most appropriate measurement method for China's national conditions by comparing. Part III designs a mathematical model for measuring the stability of local revenues based on the conclusions drawn from the literature review in Part II, and derives the corresponding measurement results. The fourth part is an economic analysis based on the measured quantitative results, which seeks to find a reasonable economic theoretical support based on the experimental results. The fifth part is to obtain corresponding conclusions based on mathematical and theoretical calculations, and to give relevant policy recommendations based on the conclusions.

II. LITERATURE REVIEW

Fiscal revenue stability is an important research topic in the macroeconomic field that has received attention in both theoretical and practical circles, and several publications have emphasized the significance of fiscal stability research. Ramey (1995) used cross-sectional data for 92 countries from 1960 to 1985 to examine the relationship between fluctuations in fiscal behavior and economic growth and discovered a negative correlation. Badinger (2009), on the other hand, examines the relationship between the volatility of fiscal behavior and the volatility of macroeconomic variables using panel data for 20 countries from 1967 to 2001 and finds a positive correlation between the volatility of fiscal behavior and the volatility of economic output, but not between the volatility of fiscal behavior and the volatility of inflation. Afonso and Furceri (2010) examine the relationship between the size and volatility of fiscal balances and economic growth using cross-sectional data for OECD and EU countries from 1970 to 2004. They find a negative relationship between the size and volatility of indirect taxes and economic growth, as well as a similar negative relationship between the size and volatility of fiscal spending and economic growth. Later, Afonso and Jalles (2012) examine the impact of fiscal stability and financial crises on economic growth using panel data for OECD countries and developing countries from 1970 to 2008, respectively, and find a negative correlation between fiscal spending volatility and economic growth. Fatas and Mihov (2013) examine the relationship between policy stability and economic growth using cross-sectional data for 91 countries from 1960 to 2000. They find that policy stability variables better explain economic growth than level variables and that policy fluctuation, such as inflation and government spending fluctuations, have a negative relationship with long-run economic growth. In terms of domestic research, Chinese scholars have emphasized the importance of stability studies. For example, Yu Yongding (2000) and Wang Guosong (2004) introduced the concept of financial stability earlier, but their studies focused on the impact of stable fiscal policies on financial markets. Jia Junxue (2012), on the other hand, investigates the significance of tax policy rules in China from 1992 to 2009 and discovers that the policy regularity of tax revenue size changes helps stabilize the inflation rate and output gap, effectively enhancing the stability of economic output, while Fang Hongsheng and Zhang Jun (2010), An Yuan and Wang Jun (2012), Li Ming and Mao Jie (2014), Zhou Bo (2014), and Zhang, J., and Pang, R. (2018) reach similar conclusions. Zeilin Huang and Baohua Zhu (2015) examine the relationship between government revenue and expenditure shocks and economic volatility using a DSGE model and find that the relationship between tax shocks and economic volatility is not significant. Wang, Liyong, and Ji Yao (2019) use a model to identify government spending volatility shocks and tax volatility shocks based on quarterly data for China from 2003 to 2017. They find, first, that fiscal volatility in China has increased significantly since the financial crisis; and, second, that there is a negative relationship between both government spending volatility shocks and total economic output.

Most of the existing literature on the measurement of revenue stability of local revenues uses elasticity indicators or growth indicators to measure the variation of local revenues, and few studies use the variance method (Wilford, 1965; Williams, 1973; Sobel and Holcombe, 1996; Dye and Merriman, 2004; Liu, Jinquan and Liu, 2005; Dong, Jin, 2006; Du, Ting, 2007; Huang, Zeilin and Zhu, Baohua, 2009; Kong, Liu-Liu and Xie, Qiao-Xin, 2009). However, in comparison to tax fluctuations, elasticity and growth indicators show more revenue growth, whereas the variance method shows the degree of revenue fluctuations better. Moreover, the majority of domestic and foreign literature that uses the variance method to measure volatility indicators uses rolling standard deviation measures (Fuzian Fang and Wei Xing, 2017; Xiaolong Wang and Long Yu, 2018; Jing Guo and Guangrong Ma, 2019). Not only is this approach highly divergent and arbitrary in terms of the rolling window period's interval span and interval structure, but the rolling standard deviation indicator can only measure the overall fluctuations of a particular variable, ignoring the intrinsic linkages between various types of output or income within the structure of economic variables. For example, the intrinsic linkage between various categories within the local fiscal structure is neglected, and the fluctuations in fiscal revenues triggered by changes in the local fiscal structure cannot be effectively identified, and the stability of local fiscal revenues cannot be better measured. As a result, White (1983) improved the variance indicator of fiscal fluctuations and proposed the concept of the Portfolio Variance method (Portfolio Variance), which takes into account the residuals of the modified individual categories and their covariances and is capable of accurately measuring the local revenue triggered by the interaction of structural changes in fiscal revenue and economic base fluctuations vola.

Although many scholars at home and abroad have studied the relationship between fiscal revenue stability and economic growth, existing studies on the measurement of fiscal revenue stability are mostly focused on general statistical measurement methods, lacking systematic and standardized mathematical measurement models, and few scholars have measured the fiscal revenue of different provinces in China. As a result, it is necessary to develop scientific and reasonable local revenue indicators to accurately depict the stability of local revenue. Based on White's (1983) "combined variance method," this paper develops a method to measure the fluctuation indicators of local fiscal revenues, then measures the stability indicators of local fiscal revenues in different provinces in China, and makes policy recommendations to increase fiscal revenue stability based on the results of the indicators. The findings are used to make policy recommendations to improve fiscal revenue stability, filling a gap in the existing literature on the empirical study of measuring the stability of local fiscal revenues in China.

III. MEASURES OF FISCAL REVENUE STABILITY AND RESULTS

1. The measure of fiscal revenue stability

White's (1983) combination variance method is used to build local revenue volatility indicators, and it is an important foundation for empirically testing the stability of local revenue and its economic effects in China. To measure local revenue volatility indicators, the combination variance method is used, which is divided into three steps: the first step is to propose the fiscal revenue classification method; the second step is to measure the unit standard deviation of each type of revenue within the fiscal revenue portfolio, and the third step is to measure the fiscal revenue volatility indicators of the fiscal revenue portfolio.

Classification method of financial revenue

The corresponding classification methods are proposed to provide the necessary data classification criteria for the portfolio variance method based on the elasticity, structure, and intrinsic linkage of each subject within the fiscal revenue portfolio. In academia, there are currently more classification methods for fiscal revenues. Fiscal revenue, for example, can be divided into government public finance revenue and state-owned assets operating revenue based on the method of obtaining revenue; or fiscal revenue can be divided into recurrent revenue and temporary revenue based on the stability of obtaining revenue. Fiscal revenue can also be divided into central and local fiscal revenue based on revenue management authority; or revenue from the state-owned economy, collective economy, and various non-state-owned economies based on economic composition; or revenue from agriculture, industry, transportation, and commercial services based on economic sectors. Officially, China's local government revenues are divided into six categories: tax revenues, social insurance fund revenues, non-tax revenues, loan transfer recovery principal revenues, debt revenues, and transfer revenues. The article follows the Ministry of Finance's classification method for mathematical calculation in data collection to facilitate data collection and statistics.

Measurement of the standard deviation within the portfolio

Measuring the standard deviation of individual fiscal revenue portfolio units: The unit standard deviation of a single category's revenue within the fiscal revenue portfolio can be used to reflect the degree of fluctuation in the category's actual deviation from its expected fitted value. Assuming REV_{it} is the actual revenue of category I in period t, $\widehat{REV}_{it}$ is the expected revenue fit of category I in period t, $\overline{REV_i}$ is the mean of the revenue of category I from period 1 to period m, and m is the number of periods in the sample time span, σ_i,the unit standard deviation of revenue of category I from period 1 to period m can be defined as equation (1):

$$\sigma_i = \sqrt{\frac{\sum_{t=1}^{m}\left[\frac{REV_{it}-\widehat{REV}_{it}}{\overline{REV_i}}\right]^2}{m-1}} \quad (1)$$

In this regard, to measure the expected fitted value $\widehat{REV}_{it}$ of the fiscal revenue of tax category I in period t, assuming that there is no particularly significant change in the tax rate or tax base of each tax category during the sample interval, the Trend Regression method can be used to measure the expected fitted value $\widehat{REV}_{it}$, as shown in equation (2) shows that:

$$\ln REV_{it} = a + b \cdot t + e_{it} \quad (2)$$

where REV_{it} is the fiscal revenue of category I in period t, t is the time variable indicating the year, a and b are the corresponding regression coefficients, and e_{it} is the random error term of the model. Thus, by using the regression coefficient b, $\widehat{REV}_{it}$ can be estimated. The unit standard deviation σ_i can be estimated by substituting $\widehat{REV}_{it}$ and other relevant data into equation (1) to obtain the difference between the actual and expected fiscal revenues.

Measures of fiscal revenue volatility indicators

Measuring revenue volatility indicators of the revenue portfolio: Considering that the unit standard deviation σ_i only reflects the revenue volatility of a single category I, to accurately measure the volatility indicators of the revenue portfolio containing multiple categories, it is necessary to consider not only the unit standard deviation σ_i of the fiscal revenue of a single category I but also the covariance σ_{ij} between a single category i and any category j within the revenue portfolio. According to the definition of covariance, $\sigma_{ij} = \rho_{ij} \cdot \sigma_i \cdot \sigma_j \sigma_{ij} = \rho_{ij} \cdot \sigma_i \cdot \sigma_j$, where ρ_{ij} is the correlation coefficient between category i and category j, therefore, given a combination of n fiscal revenue categories, the Revenue Volatility Fluctuation (RV) indicator RV_t of the fiscal revenue portfolio of a region in period t can be defined as in equation (3):

$$RV_t = Revenue\ Volatility_t = \sigma_t^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} REV_i \cdot REV_j \cdot \rho_{ij} \cdot \sigma_i \cdot \sigma_j \quad (3)$$

Where REV_i and REV_j are the revenue levels of fiscal revenue category I and fiscal revenue category j, respectively, and σ_i and σ_j are the unit standard deviations of category I and category j, respectively. A higher value of RV_t means a greater degree of local revenue volatility, i.e., a weaker stability of local revenue.

When elasticity indicators, growth indicators, and variance indicators for local revenue fluctuations are compared, it is discovered that the combined variance method measures local revenue fluctuation indicators scientifically and reasonably by taking into account the intrinsic linkage between each revenue category, and is suitable for application to the study of local revenue stability in China. As a consequence, to measure China's local revenue volatility using the combined variance method, the unit standard deviation of each revenue category and the corresponding Chinese local revenue volatility indicator RV_t must be measured using the revenue structure's prescribed classification method.

It should be noted that, considering that the revenue data of different revenue categories used in this paper are in "tens of billions of yuan", then, according to the calculation process of equations (1)-(3), the final unit of the revenue fluctuation indicator will be "tens of billions of yuan squared ". The unit of "tens of billions of yuan" is used to present the measurement results more clearly, and different units do not affect the change of relative fiscal revenue fluctuations (White, 1983; Yan, 2012; He, Yang, and Wang, Wei, 2017), therefore, there is no need to worry about the choice of units, and it is feasible to choose the unit of "tens of billions of yuan" for fiscal revenue data.

2. results of the measure of fiscal revenue stability

Using White's (1983) combined variance method and sample data from 30 Chinese provinces (except Tibet) from 2000 to 2018, we can calculate the fiscal revenue volatility indicator RV for each province in China. Table 1-1 displays the results of measuring the fiscal revenue volatility indicator RV for 30 Chinese provinces from 2000 to 2018, revealing significant geographical differences

Table 1-1 Fiscal revenue volatility indicators for Chinese provinces: 2000-2018.

Unit: tens of billions of dollars squared

RV	2000	2003	2006	2009	2012	2015	2018
Xinjiang	1.14	3.02	9.73	31.83	87.92	160.81	219.46
Ningxia	0.42	0.88	3.6	13.47	47.4	102.36	106.81
Qinghai	0.61	1.19	3.7	13.47	51.63	82.37	160.02
Gansu	0.39	0.77	3.82	13.03	42.95	51.49	128.60

Shaanxi	0.38	0.63	3.71	20.44	80.61	128.56	133.14
Yunnan	1.1	2.14	6.89	31.44	145.28	54.23	78.01
Guizhou	0.46	0.9	1.64	7.72	41.06	51.85	56.65
Sichuan	0.8	1.18	2.53	6.85	25.65	30.62	42.07
Chongqing	0.87	2.72	7.84	20.4	42.93	86.5	142.08
Hainan	2.06	6.62	26.34	99.57	318.6	608.16	708.39
Guangxi	0.71	2.98	9.08	28.2	75.4	125.99	222.29
Guangdong	0.71	1.01	2.95	12.98	58.99	114.42	179.55
Hunan	0.61	1.05	3.39	11.6	42.71	80.15	115.32
Hubei	0.42	0.81	2.29	11	60.11	142.06	185.40
Henan	0.9	2.13	8.24	25.8	75.72	151.51	193.02
Shandong	0.52	0.99	3.24	11.98	40.79	88.05	148.92
Jiangxi	0.66	1.02	2.69	9.38	46.63	121.81	189.67
Fujian	0.52	1.14	3.1	10.57	45.85	93.94	169.44
Anhui	1.33	2.9	8.05	24.49	66.45	139.31	234.07
Zhejiang	0.51	0.98	2.11	8.44	32.73	61.51	73.98
Jiangsu	0.15	0.24	0.62	3.41	19.72	41.91	67.45
Shanghai	0.33	0.77	2.6	11.11	66.57	157.47	217.94
Heilongjiang	0.78	1.35	4.47	17.47	75.29	133.86	196.42
Jilin	0.34	0.6	1.72	7.06	38.17	117.54	151.33
Liaoning	0.71	1.02	2.21	9.53	40.07	51.27	74.09
Inner Mongolia	0.44	0.86	3.04	12.33	62.27	87.69	172.92
Shanxi	0.24	0.45	1.02	2.75	10.94	25.66	37.42
Hebei	0.03	0.07	0.2	0.9	3.93	7.81	7.86
Tianjin	0.05	0.1	0.33	1.37	7.24	11.35	15.58
Beijing	0.32	0.62	1.69	5.88	34.28	58.13	97.73

Tables 1-2 present the rankings of RV measures of fiscal revenue volatility indicators for 30 Chinese provinces in 2000, 2009, and 2018. On the one hand, comparing the degree of change in the ranking of fiscal revenue volatility indicators in different provinces between 2009 and 2000, while accounting for the shock of the 2008 financial crisis, can reflect the impact of shocks such as the financial crisis on the stability of local fiscal revenue. On the other hand, considering the pilot reform of "camp conversion" by region and industry from 2012 to 2016, comparing the degree of change in the ranking of fiscal revenue fluctuation indicators in 2018 and 2009 in different provinces can reflect the impact of "camp conversion" as a representative of the impact of tax structure change on the stability of local fiscal revenue.

Table 1-2 Ranking of fiscal revenue volatility indicators for Chinese provinces: 2000-2018

Unit: tens of billions of dollars squared

RV	2000	2000 Ranking	2009	2009 Ranking	2018	2018 Ranking
Hainan	2.06	1	99.57	1	708.39	1
Anhui	1.33	2	24.49	6	234.07	2
Guangxi	0.71	11	28.20	4	222.29	3

Xinjiang	1.14	3	31.83	2	219.46	4
Shanghai	0.33	25	11.11	17	217.94	5
Heilongjiang	0.78	8	17.47	9	196.42	6
Henan	0.90	5	25.80	5	193.02	7
Jiangxi	0.66	12	9.38	21	189.67	8
Hubei	0.42	21	11.00	18	185.40	9
Guangdong	0.71	10	12.98	13	179.55	10
Inner Mongolia	0.44	19	12.33	14	172.92	11
Fujian	0.52	15	10.57	19	169.44	12
Qinghai	0.61	14	13.47	11	160.02	13
Jilin	0.34	24	7.06	24	151.33	14
Shandong	0.52	16	11.98	15	148.92	15
Chongqing	0.87	6	20.40	8	142.08	16
Shaanxi	0.38	23	20.44	7	133.14	17
Gansu	0.39	22	13.03	12	128.60	18
Hunan	0.61	13	11.60	16	115.32	19
Ningxia	0.42	20	13.47	10	106.81	20
Beijing	0.32	26	5.88	26	97.73	21
Yunnan	1.10	4	31.44	3	78.01	22
Liaoning	0.71	9	9.53	20	74.09	23
Zhejiang	0.51	17	8.44	22	73.98	24
Jiangsu	0.15	28	3.41	27	67.45	25
Guizhou	0.46	18	7.72	23	56.65	26
Sichuan	0.80	7	6.85	25	42.07	27
Shanxi	0.24	27	2.75	28	37.42	28
Tianjin	0.05	29	1.37	29	15.58	29
Hebei	0.03	30	0.90	30	7.86	30

As shown in Table 1-2, the top ten provinces of local fiscal revenue fluctuation indicators in 2000 were Hainan, Anhui, Xinjiang, Yunnan, Henan, Chongqing, Sichuan, Heilongjiang, Liaoning, and Guangdong in that order; the top ten provinces of local fiscal revenue fluctuation indicators in 2009 were Hainan, Xinjiang, Yunnan, Guangxi, Henan ， Xinjiang, Yunnan, Guangxi, Henan, Anhui, Shaanxi, Chongqing, Heilongjiang, and Ningxia in order; the top 10 provinces of local fiscal revenue fluctuation indicators in 2018 were Hainan, Anhui, Guangxi, Xinjiang, Shanghai, Heilongjiang, Henan, Jiangxi, Hubei, and Guangdong in order. It can be found that Hainan, Guangxi, Xinjiang, Anhui, Heilongjiang, Henan, Ningxia, and other local fiscal revenue fluctuation indicators have been in the top 10 for a long time, with Hainan being the highest. The rest of the fluctuation indicators are mostly concentrated in the central and western provinces, with Xinjiang, Guangxi, and other remote provinces fluctuating more. Hebei, Tianjin, Jiangsu, and other coastal provinces and municipalities directly under the Central Government fluctuate relatively little and are frequently at the bottom of the list.

Comparing the changes in the ranking of fiscal revenue volatility indicators of different provinces in 2009 and 2000, we can see that the impact of the financial crisis has significantly increased the ranking of fiscal revenue volatility indicators of Shaanxi and Ningxia, from 23rd and 20th to 7th and 10th.The ranking of fiscal revenue volatility indicators in Guangxi, Gansu and Inner Mongolia also increased to some extent, which means that the financial crisis shock raised the fiscal revenue volatility in Shaanxi, Ningxia, Guangxi, Gansu and Inner Mongolia, thus reducing the stability of their fiscal revenues. On the contrary, the ranking of fiscal revenue volatility indicators in Sichuan and Liaoning show significant decreases, from 7th and 9th to 25th and 20th, respectively, and the ranking of fiscal revenue volatility indicators in Jiangxi also decreases to some extent, which implies that the financial crisis shock reduces the fiscal revenue volatility of Sichuan, Liaoning and Jiangxi, thus improving the stability of their fiscal revenues.

Considering the "camp reform" pilot reform by region and industry from 2012 to 2016, and comparing the changes in the ranking of fiscal revenue volatility indicators of different provinces in 2018 and 2009, we can see that the impact of the "camp reform" on Shanghai and Jiangxi's fiscal revenue volatility indicators is significant. Fiscal revenue volatility indicators have risen significantly in rank, from 17th and 21st to 7th and 8th, respectively. The ranking of fiscal revenue volatility indicators in Hubei, Fujian, and Jilin also increased to some extent, indicating that the structural change in fiscal revenue represented by the "camp reform" has increased fiscal revenue volatility in Shanghai, Jiangxi, Hubei, Fujian, and Jilin, reducing fiscal revenue stability. On the contrary, the ranking of fiscal revenue volatility indicators in Yunnan and Chongqing falls significantly, from third and eighth place to 22nd and 16th place, respectively, and the ranking of fiscal revenue volatility indicators in Ningxia and Shaanxi falls to a lesser extent, indicating that the structural change in fiscal revenue represented by the "camp reform" reduces fiscal revenue volatility in Yunnan, Chongqing, Ningxia, and Shaanxi. Thus increasing the stability of its fiscal revenues

By comparing changes in the ranking of fiscal revenue volatility indicators in China between 2000, 2009, and 2018, the typical fact of local fiscal revenue volatility in China is confirmed on the one hand, namely, the indicators of fiscal revenue volatility show significant geographical differences. The degree of volatility is higher in economically developed eastern coastal regions than in less developed central and western regions, and it is significantly higher in economically active southern regions than in northern regions, with the overall degree of volatility decreasing from east to west and south to north. On the other hand, by comparing the degree of fluctuation before and after external shocks, the "camp reform" and external shocks such as the financial crisis have the same positive impact on the fluctuation of local fiscal revenue.

IV. ANALYSIS OF MEASUREMENT RESULTS

Due to large disparities in the economic base, history and culture, natural endowment, and so on between different regions in China, particularly the rapid economic development of the eastern region at the beginning of reform and opening up, China has a large problem of unbalanced regional economic development, which has led to large differences in the basic situation of fiscal revenue in each region. Therefore, this chapter attempts to explain the regional differences in the fluctuations of local fiscal revenues in China through economic analysis and the underlying mechanisms of the impact of external shocks, such as the "camp reform" and the financial crisis, on the fluctuations of local fiscal revenues in different regions.

The role of factors of production in determining regional economic development is revealed by Neoclassical economic theory, with material capital, human capital, and the level of technology as measured by total factor productivity (TFP) determining the level of economic development of a region. According to Shu, Yuan, and Xu, Xianxiang (2002), China's economic growth model is primarily of the AK type, i.e., China's economic growth is primarily based on physical capital accumulation. Southern and eastern regions have a stronger economic base and more capital accumulation, which makes their fiscal revenues more stable and resilient to external shocks, whereas northern and western regions have less capital accumulation, owing to the recent decline in economic activity, causing the stability of local fiscal revenues to decline gradually from south to north and east to west.

The difference in economic structure also contributes to regional differences in fiscal revenue stability. Since the establishment of the Shenzhen Special Zone in 1979 to the identification of 14 coastal open cities in 1984 and the opening up of economic open zones in the eastern regions of the Yangtze River Delta, Pearl River Delta, Southeast Fujian, and the Bohai Rim in 1985, China's reform and opening up has not progressed neatly in the development process. As a result, there are clear differences between regions in terms of industrial structure, level of nationalization, and level of marketization. Among these, the proportion of primary, secondary, and tertiary industries in GDP, as an important indicator for measuring the industrial structure of regional economies, can better reflect the significant differences in economic structure across China's regions.

Table 2 Industrial structure distribution of provincial governments

Ranking	Region	GDP (Billion)	Percentage of primary industry	Percentage of secondary industry	Percentage of tertiary industry
1	Guangdong	107671.07	4.04%	40.44%	55.51%
2	Jiangsu	99631.52	4.31%	44.43%	51.25%
3	Shandong	71067.50	7.20%	39.84%	52.96%
4	Zhejiang	62352.00	3.36%	42.61%	54.03%
5	Henan	54259.20	8.54%	43.51%	47.95%
6	Sichuan	46615.82	10.31%	37.25%	52.44%
7	Hubei	45828.31	8.31%	41.67%	50.01%
8	Fujian	42395.00	6.12%	48.55%	45.33%
9	Hunan	39752.12	9.17%	37.60%	53.23%
10	Shanghai	38155.32	0.27%	26.99%	72.74%
11	Anhui	37114.00	7.86%	41.44%	50.82%
12	Beijing	35371.30	0.32%	16.16%	83.52%
13	Hebei	35104.50	10.02%	38.73%	51.24%
14	Shaanxi	25793.17	7.72%	46.45%	45.83%
15	Liaoning	24909.50	8.74%	38.26%	52.99%
16	Jiangxi	24757.50	8.31%	44.19%	47.50%
17	Chongqing	23605.77	6.57%	40.23%	53.20%
18	Yunnan	23223.75	13.08%	34.28%	52.64%
19	Guangxi	21237.14	15.95%	33.33%	50.72%
20	Inner Mongolia	17212.50	10.82%	29.62%	49.56%
21	Shanxi	17026.68	4.84%	43.77%	51.38%
22	Guizhou	16769.34	13.60%	36.13%	50.27%
23	Tianjin	14104.28	1.31%	35.23%	63.45%
24	Heilongjiang	13612.70	23.38%	26.56%	50.06%
25	Xinjiang	13597.11	13.10%	35.27%	51.63%
26	Jilin	11726.80	10.98%	35.26%	53.76%
27	Gansu	8718.30	12.05%	32.83%	55.12%
28	Hainan	5308.94	20.35%	20.70%	58.95%
29	Ningxia	3748.48	7.47%	42.28%	50.26%
30	Qinghai	2965.95	10.18%	39.10%	50.72%

Data source: National Bureau of Statistics

According to data published by the National Bureau of Statistics and provincial and municipal statistical bureaus, provinces with poor fiscal stability, such as Hainan, Guangxi, Xinjiang, and Anhui, have a relatively high share of primary industry and a relatively low share of secondary and tertiary industry, indicating that the economic structure represented by the industrial structure is an important factor in determining fiscal revenue stability.

Geographic location is also an important factor in determining fiscal revenue stability. Zhao, Ai-Feng (2014) discovered that the natural environment, transportation conditions, climatic conditions, and geopolitical conditions caused by geography are all important factors that affect the fiscal status of different regions of China in a study on the differentiation of fiscal revenues in different regions of China. China's topography is stepped from west to east, with highlands in the west and lowlands in the east. The western part is mountainous with complex topography, with sparse vegetation, mostly grassland Gobi, and a harsh natural environment, particularly in the northwestern provinces of Qinghai, Xinjiang, and Inner Mongolia. The eastern coastal region is characterized by plains and hills, as well as good transportation and a humid climate, making it suitable for human production activities. Furthermore, the eastern coast is located on the Pacific Ocean's west coast, and there are many good ports along the coast to facilitate communication with the outside world, making it suitable for trade activities that will drive the economic development of the entire eastern region. The central and western regions are far from the Asia-Pacific region's economic center, with more inconvenient traffic, higher transportation costs for businesses, and a weaker investment environment. Furthermore, the western border region is located in Asia and Europe's hinterland, with many ethnic groups, and the surrounding security situation is also far from the eastern coastal region. Ethnic and political conflicts have a greater impact on the region's economic development and fiscal revenue stability.

V. CONCLUSIONS AND POLICY RECOMMENDATIONS

This paper first clarifies the definition of fiscal revenue volatility, then builds an indicator of local revenue stability based on White's (1983) combined variance method, and finally presents the results of measuring local revenue stability in China based on the institutional background of local fiscal structure and typical facts of local fiscal volatility in China to provide mathematical support for the subsequent study of the impact of fiscal revenue stability on the economic role of fiscal revenue stability.

The results of the combined variance method measure show that there are significant geographical differences in the fluctuation of local fiscal revenues in China. By comparing the changes in the ranking of fiscal revenue volatility indicators in China in 2000, 2009 and 2018, it confirms the typical fact of local fiscal revenue volatility in China, on the one hand, that fiscal revenue volatility indicators show significant geographical differences. The degree of volatility is lower in the economically developed eastern coastal regions than in the economically less developed central and western regions, and it is significantly lower in the economically active southern regions than in the northern regions, with the overall degree of volatility decreasing from east to west and south to north. However, when the degree of fluctuation before and after external shocks is compared, the "camp reform" and external shocks such as the financial crisis have the same positive impact on the fluctuation of local fiscal revenue.

We can conclude from the economic analysis of the experimental results that regional differences in fiscal revenue stability are primarily caused by factors of production, economic structure, and geographical location. On the one hand, a solid economic foundation, capital accumulation, and an efficient industrial structure all contribute to fiscal stability. The comparison of the industrial structure ratio and fiscal revenue stability among 30 provinces, autonomous regions, and municipalities directly under the central government reveals that fiscal revenue stability is relatively better in regions with higher economic volume and more secondary and tertiary industries, while fiscal revenue stability is relatively worse in provinces with higher primary industries, such as Hainan and Guangxi. Geographic location and other objective natural conditions, on the other hand, are important factors limiting economic development and fiscal revenue stability. The central and western regions have a large gap with the eastern coastal regions in terms of natural environment, transportation conditions, ecological environment, and geopolitical conditions, which directly leads to a large gap in the region's economic development level and the stability of fiscal revenue.

Fiscal revenue is an important grip for local governments' regulation and participation in economic activities because it is the primary source of funding for them to perform public service functions. Fiscal revenue fluctuations can disrupt the government's ability to perform economic functions, reduce the quantity and quality of public services, and result in inefficient government activities. The economic and social activities carried out by governments at all levels in practice are diverse and can be classified for different purposes and from different perspectives, but regardless of the classification method, stable fiscal revenue is the core guarantee of the government's economic activities, which is in the position of "affecting the whole body by one hair". According to empirical tests and theoretical analysis, the government should pay attention to the disparity in fiscal revenue stability across regions, actively improve the economic foundation of the less stable central and western regions, formulate differentiated economic and fiscal policies, vigorously develop secondary and tertiary industries, and improve fiscal revenue stability to deal with regional economic risks and improve government administrative efficiency.

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Radiology and Imaging Diagnosis in Undergraduate Medicine in a Curriculum using Active Methodologies: A Systematic Review from 2011 to 2021

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Abstract— *Radiology is a medical specialty that renews itself and advances every day, in a process of modernization that, in addition to investments, requires a continuous effort to update. The use of radiological images is a fundamental part of learning because of its availability and undeniable clinical relevance. Thus this study will make it possible to review how the teaching and learning of radiology and diagnostic imaging in medical education is developed in an integrated and interdisciplinary undergraduate curriculum in medicine. Objective: To identify the importance of radiology and diagnostic imaging in undergraduate medical education in a curriculum using active methodologies. Methodology: The present study is a systematic literature review, therefore it does not require ethics committee approval, it was carried out from a screening of articles in the period from January 2011 to March 2021 from two electronic databases: PubMed and Science Direct. The descriptors used in the search were "radiology" AND "medical education". Academic articles were searched for authors who correlated Active Methodologies, Medical Education, Transversal Teaching in Medical Graduation, Radiology and Diagnosis. Results and Discussion: Studies that had Active Methodologies, Medical Education or Radiology and diagnosis were included in this review, as well as literature review studies that accounted for 05 articles and editorials. To better understand the role of radiology in medical practice, it is necessary to review its history in medicine. Since the advent of imaging exams, radiology and diagnostic imaging have presented important advances in several areas. Its implementation in the curriculum was addressed by the author AL QAHTANI et al, 2014, in which he pointed out the importance of a cross-curriculum for the insertion of the axis of this skill and not only a discipline in a single period of the course, because the* *content is related to other areas of Medicine, such as Medical Pathology, Human Anatomy and Emergency and Urgent Care.With all this mentioned, it should be understood that the teaching environment should be seen as a place of individual and collective transformation, being receptive to new methodologies and new approaches to teaching and insertion of new skills to the students.*

***Keywords*— medical education, radiology and active methodologies.**

I. INTRODUCTION

Radiology is a medical specialty that renews itself and advances every day, in a process of modernization that, in addition to investments, requires a continuous effort to update. Intrinsically linked to technological development, diagnostic imaging methods allow the physician to obtain information even imagined less than ten years ago, with a speed and efficiency that enhance medicine as a whole (SCATIGNO NETO,2019). The use of radiological images is a fundamental part of learning because of its availability and undeniable clinical relevance. Some studies indicate that the "early" insertion of this skill enriches the understanding of pathophysiological processes as well as anatomy. This is due to rapid technological advances, the availability and use of alternative resources for teaching anatomy and correlation with the clinic (KALAMI TR et al. , 2016). It plays an important role in modern medicine as imaging technologies have revolutionized the clinical practice of medicine in Brazil and worldwide, (CORR P. 2012), but many of the students are not properly introduced/prepared for the discipline during the first years of college or are introduced to the discipline in a non-adversarial manner.(BRANSTETTER BF et al., 2017).Radiology and diagnostic imaging represents relevant knowledge in medical education, helping in clinical diagnosis. Since this is a new study, the research is faced with the lack of current literature that demonstrates its importance.However, many students are not properly introduced/prepared for this competency during the first years of college (BRANSTETTER BF et al., 2017). Concomitantly, in most medical schools in Brazil, the set of operational and interpretative skills in radiology and diagnostic imaging is not mandatory, despite the recognition of its importance.(SILVA et al. , 2019, p.97). Medical undergraduate courses should provide theoretical and practical knowledge of radiological examinations directed to different clinical settings (AL QAHTANI et al, 2014). Thus, this study will make it possible to review how the teaching and learning of radiology and diagnostic imaging are developed in medical education, in an integrated and interdisciplinary undergraduate medical curriculum.

II. OBJECTIVE

2.1 Objective General: Identify the importance of radiology and diagnostic imaging in undergraduate medical education in a curriculum using active methodologies. 2.2 Specific Objective: To

understand the role of radiology in the current practice of medicine and reflect on the teaching of radiology in undergraduate medical courses, based on the available literature; Identify the teaching of radiology and applied diagnostics across the board in medical school.

III. METHODOLOGY

3.1 TYPE OF STUDY.

The present study is a systematic literature review, therefore it does not require ethics committee approval, it was conducted from a screening of articles in the period January 2011 to March 2021 from two electronic databases: PubMed and Science Direct. The descriptors used in the search were "radiology" AND "medical education". Academic articles were searched for authors who correlated Active Methodologies, Medical Education, Cross-cutting Teaching in undergraduate medical education, Radiology, and diagnosis.

3.2 INCLUSION AND EXCLUSION CRITERIA

Inclusion criteria were: 1) studies with medical students or directed to medical students, 2) studies with medical residents, and 3) studies that evaluate the use of technological development in teaching human anatomy. Excluded were: 1) studies with animals, 2) studies with students from other health courses, and 3) studies involving the surgical field or surgical technique.

3.3 DATA ANALYSIS

The data were analyzed by means of analytical reading, ordering the information collected as specified in the result item, seeking to obtain the answer to the research objective.

IV. RESULTADOS

It is presented in the flowchart in Figure 1 to generally simplify the selection of articles performed by the researchers. Thus, studies that had Active Methodologies, Medical Education or Radiology and diagnosis were included in this review, as well as literature review studies that accounted for 05 articles and editorials.

Chart 1 - collected and used academic articles

AUTHORS	TITLE	SUMMARY
Fahd Al Qahta ni and Adel Abdelaziz.	"Integrating radiology vertically into an undergraduate medical school curriculum: a three-phase integration approach". radiologyvertically into an undergraduate medical school curriculum: a three-phase integration approach".	At Al-Baha University School of Medicine, Al-Baha, Saudi Arabia, efforts have been made to integrate radiology vertically and in a structured way into the undergraduate curriculum from the first to the sixth year.
Alexandre Ferreira da Silva, Robson José de Souza Domingues, Kátia SimoneKietzerJofre and Jacob da Silva Freitas	"Medical Student Perceptions of the Insertion of Radiology into Undergraduate Education Using Active Methodologies."	Radiology in the medical course has reached a new dimension not only as acomplementary diagnostic tool, but also for its use as a teaching tool, integratedwith the study of anatomy and pathology, among other subjects.
Pablo Antonio Maia from Farias, Ana Luiza de Aguiar Rocha Martin, Cinthia Sampaio Cristo.	"Active Learning in Health Education: HistoricalCourse and Applications"	This literature review describes a brief historical background of education, arriving at student-centered education, as well as some of the most commonly used active learning methods today.
Jennifer ELim-Dunham,David C Ensminger, JohnA McNulty.	"An online radiology curriculum vertically integrated developed as cognitive learning: impact on student performance and learning"	We describe the development of the online vertical radiology curriculum and evaluate its impact on student performance and the learning process using a mixed-methods approach
Barton FBranstetter, Laura E Faix Allen L Humphrey	"Medical student preclinical training in radiology: the effect of early exposure."	The purpose of this study was to determinewhether an integrated radiology curriculum in the first year of medical school changesmedical students' attitudes toward radiology or affects their knowledge of

From the analysis, the articles were separated into 3 themes as research categories, and the following descriptors were considered: Medical education and radiology and diagnostic imaging; active methodologies and the curricular guidelines for medical education; transversality of the teaching of radiology and diagnostic imaging in medical education.

V. DISCUSSION

5.1 UNDERSTANDINGS OF THE IMPORTANCE OF THE ROLE OF RADIOLOGY AND DIAGNOSTIC IMAGING IN MEDICAL EDUCATION.

In order to better understand the role of radiology in the medical practice, it is necessary to review its history in medicine. Since the advent of imaging exams, radiology and diagnostic imaging have represented important advances in several areas. Thus, it is essential that there are professionals trained to know the techniques and proper use of these complementary exams (CHEN et al., 2006), since the improper use of these tests implies damage to both the patient and the health system (SILVA et al., 2019).Consequently, preparing medical students to become responsible users of medical imaging, including, to this end, the teaching of radiology and diagnostic imaging in the undergraduate medical curriculum, is an increasing target of attention (LIM-DUNHAM, 2016). Some authors, such as Lewis and Shaffer, make several accounts of the importance of inserting the Axis of radiology and diagnostic imaging in the academic curriculum of the medical course, such as: teaching skills needed to interpret radiographs on an emergency basis; developing appropriate and feasible algorithms for requesting imaging methods for common clinical conditions (Lewis and Shaffer, year). In addition to understanding the concept of positive and negative predictive values of imaging exams and how to incorporate them into patient management; understanding the risks, contraindications, and limitations of imaging methods; following the exams so they can explain them to their future patients; improving their view of the disease, physiology, and anatomy; understanding the benefits of clinicaloradiologist collaboration, from the correct completion of applications and familiarization with image-guided procedures (Lewis and Shaffer, 2017).

With all this mentioned, the importance of teaching radiology and diagnostic imaging, using active devices and methodologies is unquestionable, and these must be well applied, with theories and their applicability in practice, as advocated by Piaget's constructive ideas, giving a new embodiment, a meaningful learning.

5.2 THE USE OF ACTIVE METHODOLOGIES IN LIGHT OF THE NEW CURRICULAR GUIDELINES FOR THE MEDICAL COURSE

The National Curriculum Guidelines (DCNs) of the undergraduate course in Medicine (BRASIL, 2014) defines the organization, development and evaluation of the course, within the scope of the country's higher education system and guides to the promotion of integration and interdisciplinarity in coherence with the curriculum development axis, and the use of methodologies that favor the active participation of the student in the construction of knowledge.Among the elements that make up active methodologies, two actors must be considered conceptually: the teacher, who no longer has the role of lecturer or teacher, leaving him/her with the task of facilitating the process of knowledge acquisition; and the student, who begins to receive names that refer to the dynamic context, such as student or learner.A better teaching strategy for radiology and diagnostic imaging is not so well addressed in studies, but, proactive solutions of updating should be thought for graduation. Methodological strategy that requires the active participation of the student in the construction of knowledge, its use in the teaching of radiology and diagnostic imaging in the medical course can be encouraged (Dawson et al.,2017).

Dawson et al. in a recent study demonstrated that the technique of realistic simulation, a proactive action performed mostly in medical residencies and continuing education, was effective for the acquisition of required skills. This type of activity promotes the development and improvement of theoretical and practical skills, as well as crisis management and free decision making, in a significant way, from the simulation-based teaching methodology.

5.3 ANALYSIS OF THE TRANSVERSAL TEACHING OF RADIOLOGY AND DIAGNOSTIC IMAGING IN MEDICAL EDUCATION.

In this sense, some doubts emerged related to the model, the content and the ideal period to introduce the learning of radiology and diagnostic imaging, showing the need for the elaboration of an effective means for teaching this content (SILVA et al., 2019).AL QAHTANI et al (2014), highlights that at Al-Baha University Faculty of Medicine (ABUFM) in Al-Baha - Saudi Arabia - it was scored that the best time should be during the early stages of the medical school curriculum .Alternatives to answer this question were to address radiology within other clinical disciplines through a "when indicated" approach, allocate a distinct, specialized module, or integrate a related topic longitudinally into the curriculum during their 6 academic years (AL QAHTANI et al, 2014).Since a large part of medical education routinely uses imaging studies, consequently, at some point during the undergraduate or professional life, it will be necessary to interpret imaging exams, regardless of the area, according to some of the studies discussed.In the new integrated and interdisciplinary curricula with the use of active methodologies in undergraduate medicine, the teaching of radiology and diagnostic imaging became part of the axis Attention and Health Education (AES), in the morphofunctional laboratory (LMF) (UNIFAMAZ, 2017), developed in some periods, with active methodologies and favoring the teaching method in vertically integrated internships. The assimilation of content by this means allows a lasting learning, relevant in practical and real clinical work of students (LIM-DUNHAM, 2016).The evaluation of the development of competencies in radiology and diagnostic imaging by the medical student in an integrated and interdisciplinary curriculum, using active methodology, is of significant importance for the formation of the medical professional.Since according to recent studies, the breakdown of disciplines and their reorganization in integrative axes, promotes the union of knowledge, facilitating from the physiopathological understanding, clinical context, and mainly associating to these the complementary radiological imaging exams for a broad understanding, since, previously, medical schools used a compartmentalized disciplinary structure.

VI. CONCLUSION

It is not new that the teaching of radiology and diagnostic imaging is going through a transformation moment, once its importance is already recognized, as mentioned by some authors, and the need to develop this medical knowledge is unquestionable: interpretation of radiographs in an emergency, when to request complementary imaging exams, are some examples of its great value in teaching and learning for medical graduation, forming general practitioners skilled in this knowledge.Its implementation in the curriculum was addressed by the author AL QAHTANI et al, 2014, in which he pointed out the importance of a transversal curriculum for the insertion of the axis of this skill and not only a discipline in a single period of the course, because the content is related to other areas of Medicine, such as Medical Pathology, Human Anatomy and Emergency and Urgent Care, among others.It was also observed the positive predictive value of the teaching of this axis, incorporating the active and integrative teaching methodologies, as already mentioned, some sites already use even realistic simulation resources for the use of this radiological apparatus for the proper learning of the student, as well as its early insertion.With all this mentioned, it should be understood that the teaching environment should be seen as a place of individual and collective transformation, being receptive to new methodologies and new approaches to teaching and to the insertion of new skills for the students.

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